This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

UC-NRLF
$B 77 642

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

State Engineer

OREGON COOPERATIVE WORK

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
IN COOPERATION WITH
STATE OF OREGON

SILVER LAKE PROJECT

Irrigation and Drainage

BY

JOHN T. WHISTLER
ENGINEER U. S. RECLAMATION SERVICE

JOHN H. LEWIS
STATE ENGINEER FOR OREGON

OCTOBER, 1915

Digitized by Google

Digitized by Google

TC824
O7A5245

CONTENTS

I

Page

Synopsis 7
Introduction 14
Authority 14
Agreements 14
Organization 15
Location and General Description 15
Settlement 17
Transportation and Markets 17

II

General Information Relating to the Project 19
Climate 19
Temperature and Rainfall 19
Probable Influence of Climate on Nature of Crops 33
Geology 40
Water Resources 43
Paulina Marsh Drainage 43
Sycan Marsh Drainage 46
Silver Lake Drainage 47
Wells and Domestic Supply 50
Springs 56
Artesian Supply 56
Gaging Stations and Records of Flow 58
Early Investigations and Surveys 66
U. S. Reclamation Service-Landes, 1904 66
U. S. Reclamation Service-Jacobs, 1908 (unpublished) 67
U. S. Geological Survey-Waring, 1908 67
U. S. Geological Survey-Henshaw, 1912 67

III

Investigations for this Report 69
Reservoir Sites 71
Thompson Valley—Silver Creek 71
Emory Site—Buck Creek 72
Egli Site—Silver Creek 72
Other Sites 73
Canal Lines 75
Sycan Canal 75
Long Creek Canal 76
Silver Lake Canal 76
West Canal 77
Irrigable Lands—Topography 77
Soil and Agricultural Survey 78
Description of Area 78
Climatic Conditions 79
Agricultural Conditions 79

Digitized by Google

Page

Soils 80
Soil Fertility and Alkali 84
Irrigation 85
Drainage 86
Probable Value of Irrigation and its Effect 87
Land Ownership 88

IV

General Discussion of Problems and Project Proposed 89
Existing Water Rights and Probable Supply Available for Other Lands 89
Silver Creek 90
Buck Creek 93
Bridge Creek 93
Sycan Marsh Tributaries 93
Reliability of Estimates 97
Duty of Water and Irrigating Season 98
Present Use on Wild Hay Lands 99
Investigations in Idaho-Bark 99
Investigations on Experimental Farm at Redmond, Oregon 102
Probable Crops in Future with Extended Irrigation 103
Water Duty of Different Crops 104
Relation of Water Duty to Drainage 104
Other Factors entering into Determination of Duty 105
Value and Economic use of Water 106
Duty Assumed for this Report 107
Seepage and Evaporation Losses 108
Reservoirs 108
Canals 110
Proposed Project 111
Water Required 112
Water Supply 113
Storage Requirements 115
Proposed Stages of Development 116
Silver Lake Unit 116
Paulina Unit 117
Horning Bend and Fort Rock Units 117
Possible Extensions 117
Paulina Marsh Reclamation 117
Silver Lake Bed Reclamation 121
Pumping to Additional Lands—Fort Rock Valley 124
Pumping from Ana River Springs—Summer Lake Valley 127

V

Construction Designs and Estimates of Cost for Completed Project 131
Sycan Canal 131
Estimated Cost of Sycan Canal 131
Long Creek Canal 131
Estimated Cost of Long Creek Canal 132
Thompson Valley Reservoir for Completed Project 132
East Dam 133
West Dam 134
Spillway 134
Estimated Cost Thompson Valley Reservoir and Lands 135
Total Cost—Thompson Valley Storage for Completed Project 135
Silver Creek Diversion Dam 136
Silver Creek Diversion Dam—Estimated Cost 136
Cost per Acre Foot at Diversion 137
Distributing System 137
Silver Lake Canal and Distributing System 138
Estimated Cost of Silver Lake Canal 139
Estimated Cost of Distributing System—Silver Lake Unit 139

Digitized by Google

Page

Total Estimated Cost Silver Lake Canal and Distributing System, Silver Lake Unit 140
West Canal and Distributing System....140
Estimated Cost West Canal....141
Estimated Cost Horning Bend Lateral....142
Estimated Cost of Distributing System....142
Estimated Cost of West Canal and Distributing System....142
Total Construction Cost of Gravity Project Completed....143

VI

Construction Designs and Estimates of Cost for Development by Stages..144
First Stage Development—Silver Lake Unit 144
Thompson Valley Reservoir for First Stage Development....144
Estimated Cost of First Stage Development—Silver Lake Unit 147
Second Stage Development—Paulina Unit....147
West Canal for Second Stage Development....148
Estimated Cost of Second Stage Development 148
Estimated Cost of First and Second Stage Development....148
Third Stage Development—Project Completed....149
Thompson Valley Reservoir for Third Stage Development....149
Estimated Cost of Completing Thompson Valley Reservoir...150
Completion of West Canal and Distributing System....150
Estimated Cost of Third Stage Development....151
Total Cost of Gravity Project Completed by Stages....151
Comparison of Cost of Gravity Project Completed in One Stage and in Three Stages....151

VII

Construction Designs and Estimates of Cost for Possible Extensions....153
Paulina Marsh Reclamation....153
Emory Reservoir 153
Emory Reservoir—Estimated Cost....154
Cost of Water per Acre Foot at Diversion.... 155
Distributing System 155
Estimated Cost of Canals and Distributing System—Paulina Marsh 156
Paulina Marsh Drainage 156
Drainage Canal—Estimated Cost 157
Cost of Paulina Marsh Reclamation....157
Estimates of Cost for Silver Lake Reclamation....157
Estimated Cost of Power 158
Estimated Cost of Pumping 159
Estimated Cost of Silver Lake Reclamation....161
Probable Cost per Acre of Reclaiming Silver Lake Bed....161
Estimated Cost of Pumping to Additional Lands in Fort Rock Valley 162
Estimated Cost of Power 165
Estimated Cost of Pumping....165
Probable Cost per Acre 168
Estimated Cost of Pumping from Ana River Springs, Summer Lake Valley 171
Estimated Cost of Pumping 172
Estimated Cost of Distribution 173
Probable Total Cost and Cost per Acre of Ana River Project..173
Operation and Maintenance 174

VIII

Summary, Conclusions and Recommendations....177
Summary 177
Conclusions 177
Recommendations 178
Land and Water Withdrawals 178
Cost of Investigations and Report 179

Digitized by Google

MAPS AND DRAWINGS

Page
Sheet No. 19—General Topographic Map—Silver Lake Project..... 76
Sheet No. 20—General Topographic Map—Sycan Marsh and Thompson Valley 76
Sheet No. 21—Soil Survey of Irrigable Lands..... 84
Sheet No. 22—Topography—Thompson Valley Reservoir..... 72
Sheet No. 23—Topography—Emory Reservoir—Buck Creek..... 72
Sheet No. 24—Thompson Valley Reservoir—Dam Sites and Dam Design 132
Sheet No. 25—Silver Creek Diversion Dam—Topography and Design....136
Sheet No. 26—Egli Reservoir—Silver Creek—Topography 72
Sheet No. 27—Canal Sections—Sycan Diversion Canal 134
Sheet No. 28—Canal Sections—Long and Coyote Creek Canal and West Canal 134
Sheet No. 29—Canal Sections—West Canal 134
Sheet No. 30—Canal Sections—West Canal 134
Sheet No. 31—Canal Sections—West Canal 134
Sheet No. 32—Canal Sections—West Canal and Silver Lake Canal.....134
Sheet No. 33—Canal Sections—Silver Lake Canal.....134
Sheet No. 34—Proposed Project—Irrigable Lands and Canals.....112
Sheet No. 35—Buck Creek Dam—Emory Site—Topography and Design..154
Sheet No. 36—Silver Creek Hydrograph—Available Storage at Thompson Valley 90
Sheet No. 37—Drainage Map—Silver Lake and Sycan Marsh Drainage Areas, Reservoir Sites and Gaging Stations..... 44
Sheet No. 38—General Map—Silver Lake Project..... 16
Sheet No. 39—Long Creek and Sycan Canals—Thompson Valley Reservoir 76
Sheet No. 40—Hydrograph—Recorded Discharges Silver Creek and Chewaucan River and Estimated Discharges of Long and Coyote Creeks, Sycan River and Choctoot Creek..... 46
Sheet No. 41—Land Ownership Map, Sycan Marsh and Thompson Valley 88
Sheet No. 42—Land Ownership Map, Irrigable Area..... 88
Sheet No. 43—Public Land Withdrawals.....178

ILLUSTRATIONS

Page
Plate No. 1—Fort Rock From the Town of Fort Rock..... Frontispiece
Plate No. 2—Upper Fort Rock Valley—Looking toward Fort Rock from Horning Bend ..... Frontispiece
Plate No. 3—Silver Lake From Road Near Summit to Summer Lake—Looking Northwest 40
Plate No. 4—Paulina Marsh From the North End..... 40
Plate No. 5—Grubbing Sage-brush in Fort Rock Valley. Sage-brush used for Fuel 88
Plate No. 6—Engine Using Sage-brush for Fuel in Plowing the Cleared Land—Fort Rock Valley..... 88
Plate No. 7—Pumping from a Well in Fort Rock Valley.....124
Plate No. 8—Silver Lake—Looking West.....124

Digitized by Google

SILVER LAKE PROJECT
Irrigation and Drainage

SYNOPSIS

(1). This report is the third of a series of reports under Oregon Co-operative Work, of which the Deschutes Project was the first, and Ochoco Project and Crooked River Investigations the second. It deals with irrigation and water power possibilities of the Silver Lake region, Lake County, Oregon, together with reclamation of Silver Lake and Paulina Marsh by drainage and pumping.

(2). The principal development proposed is the irrigation by storage and gravity water supply of some 16,000 acres in the vicinity of the town of Silver Lake, and approximately 32,000 acres about Fort Rock.

(3). The work has been carried on by the United States Reclamation Service and the State Engineer's office under an agreement referred to in body of the report.

(4). The features to which this report has special reference are:

(a). The irrigation of lands about Silver Lake and Fort Rock by storage of about 60,000 acre feet of water at Thompson Valley, into which diversion canals from Sycan River and Long and Coyote Creeks will divert the spring run-off from these streams. The cost of this feature is estimated at about $28.10 per acre.

(b). The reclamation and irrigation of about 9,000 acres of Paulina Marsh by storage on lower Buck Creek at the Emory reservoir site and a drainage canal through the marsh to Silver Lake, at an estimated cost of $25.20 per acre.

(c). The possible development of summer power on Silver Creek from Thompson Valley storage for use in pumping to reclaim part of Silver Lake Bed; in pumping from ground water to supply additional lands in Fort Rock Valley, and in pumping from Ana River Springs for the irrigation of about 20,000 acres of land in Summer Lake Valley.

(5). The purpose of this co-operative work is the making of detailed surveys and investigations of the water resources of the State of Oregon, with particular reference to promoting development of irrigation and power possibilities by private capital, by irrigation districts, or possibly by the State or the United States. Funds for carrying on the work are provided in

Digitized by Google

an appropriation of $50,000 by the State and allotment of an equal amount by the Secretary of the Interior from the Reclamation Fund. All available data heretofore obtained by the Reclamation Service for projects in Oregon, other than those under construction, are also made available by special agreement without additional appropriation by the State. The present value of such additional data is estimated to be $25,000.

(6). The area of non-irrigated lands in the vicinity of the town of Silver Lake which may be irrigated from Silver Creek, following storage development at Thompson Valley, is 7,500 acres. In addition, 4,000 acre feet of stored water may be furnished to complete an adequate supply to approximately 8,000 acres of land having adjudicated rights to about 4,000 acres, requiring the present mean annual summer flow. The total acreage benefited is 15,500 acres. The estimated average cost to the 8,000 acres for storage only is $2.00 per acre. The estimated cost to the 7,500 acres of new lands for storage and distribution system is $28.10 per acre if developed in conjunction with the project proposed. If developed as a separate project not involving Sycan water diversions, but storage of upper Silver Creek waters only at Thompson Valley, the estimated cost is $31.25 per acre.

(7). Conditions for the development of the proposed project to irrigate 48,600 acres are exceptionally favorable to development by stages, requiring a moderate investment for the first stage and increasing investments for the succeeding stages, thus saving large costs in accumulating interest charges over the development of the project if undertaken in a single stage. The required investment for each stage will be nearly proportional to the amount of new land to be irrigated.

(8). The **first stage** contemplates storage of upper Silver Creek waters at Thompson Valley, construction of a diversion dam on Silver Creek above the Egli reservoir site and of the Silver Lake Unit Canal and distributing system to serve 7,500 acres of new lands. In addition, 8,000 acres of land, now using the summer flow, will be provided with 4,000 acre feet storage, and also regulation of the summer flow. The estimated investment required is $250,000.

The **second stage** contemplates construction of the Long Creek canal of 220 second feet capacity from Long Creek to the Thompson Valley slope, a distance of six miles, the construction of the West Canal from the Silver Creek Diversion Dam to the pass between Paulina Marsh and Fort Rock Valley, and distributing system for the Paulina Unit of 9,000 acres. No additional storage development is required. The estimated investment for this stage is $534,800.

The **third and last** development planned requires: 1st, the completion of Thompson Valley storage by raising the East or

Digitized by Google

Main Dam and construction of the West Dam and spillway; 2nd, construction of the proposed Sycan Diversion Canal of 360 second feet capacity from the Sycan River, 14 miles to the Thompson Valley Divide; 3d, completion of the West Canal, Horning Bend lateral and distributing systems for the Fort Rock and Horning Bend units of 32,100 acres. The estimated investment required for this stage is $613,000.

The **total investment** for construction by stages as outlined is $1,398,000, a cost of $28.45 per acre for the proposed project, exclusive of the 8,000 acres having incomplete water rights, storage and regulation of natural flow for which is estimated at $16,000. The area benefited under the proposed project, including the 8,000 acres having incomplete water rights, is 56,600 acres.

(9). The records of discharge for lower Silver Creek are fairly complete for nine years. From these records, and a comparison with other streams in south-central Oregon, it is estimated that the mean run-off for the past twelve years is 40,400 acre feet, with an extreme maximum of 73,000 acre feet for the seasonal year 1904, and extreme minimum of 13,500 acre feet in the present year.

(10). Practically all the available run-off of Silver Creek during the irrigating season in ordinary years is now appropriated. Storage at the Egli reservoir site on Silver Creek is not feasible on account of high acre foot cost. Storage at Thompson Valley is feasible either for Silver Creek alone or for the additional waters from diversions which may be made from streams entering Sycan Marsh.

(11). There is estimated to be an excess flow in mean years of about 70,000 acre feet into Sycan Marsh which may be diverted into Thompson Valley by two canals 14 miles and 6 miles in length respectively, between March 15 and about the middle of June. With the exception of one year, 1905, when records of flow of Sycan River above Sycan Marsh were obtained and miscellaneous measurements made of Long and Coyote creeks, the estimates of discharge of these streams are based on studies of comparative drainage areas, together with comparisons of discharge with lower Silver Creek and Chewaucan River during 1905. These discharge ratios are extended into the following years of recorded discharge on the latter streams. Estimates thus derived are not dependable to a degree warranting any definite plans involving use of water from these streams unless confirmed by a number of years actual record of flow.

(12). All the available summer flow of Bridge Creek is already appropriated. The mean annual discharge, based on partial records of flow during three years and comparative studies of Silver Creek during other years, is estimated at 5,000 acre feet. The discharge of about 3,000 acre feet during the storage

Digitized by Google

period may be stored at the Owsley site, but the storage cost per acre foot for such small development will necessarily be high, and is not considered feasible under present conditions.

(13). The summer flow of Buck Creek is practically all appropriated. The annual discharge is estimated to be 15,500 acre feet. With storage at the Emory reservoir site, about 5,000 acre feet may be made available for new lands not located on Paulina Marsh, without interfering with present uses. The storage cost for this amount, however, is prohibitive at this site.

Economic use of Buck Creek waters may be best accomplished by storage and regulation at the Emory site in conjunction with drainage of Paulina Marsh by a drainage canal to Silver Lake. This would make possible a more economic use of water by lands already irrigating, and the extension of this use to other lands in the northern end of Paulina Marsh to include about 9,000 acres in all.

(14). Considerations of available water supply, extent of irrigable lands, and possibilities of irrigation by economic use of water, together with careful cultivation of land and distribution by rotation, have led to adopting for the proposed project a water duty of one acre foot delivered, per acre of irrigable land.

(15). The soils over the larger portion of the project appear to be those of old lake beds and terraces. They are generally free working loams that readily mulch, yet with fine enough material in the subsoils to have good water retaining capacities. Chemical analyses show them to be reasonably fertile in phosphorous and potash and to have medium nitrogen content. The alkali content is comparatively small.

(16). It is believed that little or no drainage will be required for the sloping lands under the proposed project. The lowest lands bordering Paulina Marsh and a few places in Fort Rock Valley will require drainage, but the expense will not be large and no estimates of it have been included in this report. The main drainage canal included in the cost of Paulina Marsh reclamation will furnish the main trunk drainage system for the entire marsh and bordering lands.

(17). The estimated cost of the principal features of the proposed project are as follows:

Sycan diversion and Sycan diversion canal	$213,000
Long and Coyote creek diversions and Long Creek canal	36,700
Thompson Valley storage, including lands	177,725
Silver Creek diversion dam	64,900
Silver Lake canal and distributing system	52,250
West Canal and distributing system	836,350
Total Construction Cost	$1,380,925

Digitized by Google

(18). With the development of the proposed project by stages as outlined, it is thought the yearly operation and maintenance charges should not exceed 75 cents per acre, as the number of miles of canals and laterals would be kept more nearly proportional to the acreage under irrigation.

(19). As a possible further development in the Paulina Marsh basin, the reclamation and irrigation of 9,100 acres naturally tributary to lower Buck Creek can best be brought about by a drainage canal through the marsh to Silver Lake and storage of Buck Creek waters at the Emory site on that creek. The mean annual discharge of Buck Creek is estimated to be 15,500 acre feet. Storage capacity of 12,000 acre feet is adopted from considerations of safety in design of dam and spillway, and to provide holdover storage as a means of regulating flow from year to year to assist in the reclamation of a part of the bed of Silver Lake. The estimated cost of such storage is $98,220; distributing canals, laterals and structures, $75,300; drainage canals, laterals and tiling, $55,780; a total construction cost of $229,300. The estimated cost per acre is $25.20.

(20). Following storage development at Thompson Valley and at the Emory site on Buck Creek, the possibility of reclaiming a part of the bed of Silver Lake is thought to be feasible. A large factor in this plan is the possibility of controlling practically the entire run-off of Silver Creek, which furnishes two-thirds of the run-off into Paulina Marsh, through the large capacity of storage as planned at Thompson Valley and the regulation of the diversions from Sycan streams in years of high run-off, in such manner as to prevent waste from the Thompson Valley reservoir, which would have to be cared for in Silver Lake.

The plan provides for storage in the north end of Silver Lake by a dyke across the lake, with an overflow channel to Thorn Lake to prevent overtopping of the dyke in years of high run-off. A pumping plant at the east end of the dyke will raise the stored water about 12 feet to a main distributing canal following the lake border. The pumping plant will also be required to pump the drainage from the 6,500 acres which it is planned to irrigate in the south end of the present lake bed.

The water supply for this reservoir will come during the non-irrigating period from the flow of lower Silver Creek and Bridge Creek, for which no storage is provided in the proposed project, and will be augmented by return seepage from the irrigation development about and on Paulina Marsh. This water supply is estimated to be 8,400 acre feet from lower Silver Creek and Bridge Creek before the irrigating season begins, and a possible return seepage from the Paulina Marsh district of 9,000 acre feet for the year. Evaporation losses on the 2,000 acre reservoir are estimated at 5,500 acre feet, netting about 12,000

Digitized by Google

acre feet for irrigating the 6,500 acres of lake bed. Power for pumping may be developed below the Silver Creek diversion dam with a fall of about 50 feet.

The estimated cost of reclaiming and irrigating this 6,500 acres of lake bed, including power development, is $173,900, or $26.75 per acre reclaimed, with an additional cost of $1.12 per acre each year for maintenance and operation of the power and pumping features.

(21). The Thompson Valley storage plans for the proposed Silver Lake Project offer an opportunity for the development of about 5,000 horse power during the months of June and July just below the proposed East Dam, where there is a fall of about 120 feet in the Silver Creek canyon in a distance of 4,000 feet.

A portion of this power may be used in pumping from Ana River Springs for the irrigation of 20,000 acres in the Summer Lake Valley. These springs have a constant flow of about 150 second feet. The estimated power required for two pumping lifts of 32 feet and 62 feet required to cover the 20,000 acres is about 1,240 horse power for June and July.

The estimated cost of construction of the pumping features for this development, including power development, is $215,400, with a yearly cost for operation and maintenance of $0.94 per acre, and for the distributing features, including canals, flumes, laterals, etc., $175,500, with a yearly cost for maintenance and operation of $0.75. Total estimated construction cost is $390,900, or $19.55 per acre, with a yearly charge of $1.69 per acre for operation and maintenance.

(22). A part of the summer power possible to develop below Thompson Valley on Silver Creek may be used for pumping from wells to irrigate additional lands in the Fort Rock and Christmas Lake valleys, providing pumping trials show favorable conditions as to porosity of substrata and sufficient ground water supply. There are so many uncertainties in connection with such pumping development that this use of power is offered only as a conditional possibility, requiring more extended studies of ground water supply and actual pumping tests from a number of wells.

An estimate has been made of the probable cost of pumping, with certain assumptions as to required depth of wells and porosity of soil, which is not to be considered a judgment of what may be expected but rather as reasonable and not improbable assumptions on which to base an estimate. The estimates so made for pumping to 30,000 acres of land in Fort Rock Valley call for an initial investment of $26.55 per acre for construction of power plant, power transmission lines and pumping units, including pumps, motors, well and pump house, with an estimated yearly cost of $3.00 per acre for depreciation, operation and

Digitized by Google

maintenance. It is shown, however, that for pumping from wells, gasoline engine power may be cheaper than electric power, even in this case, and possibly more adapted to the gradual development of an underground supply to an amount and over an area which would eventually permit the economical transmission of electric power derived from Silver Creek.

Digitized by Google

INTRODUCTION

This report is one of three published by Oregon Co-operative Work, of which Deschutes Project report was the first, Ochoco the second and Silver Lake the third. It will be followed by reports on other projects.

AUTHORITY

Authority for Oregon Co-operative Work and this report is found in the Act of Congress of June 17, 1902 (32 Stat., 388), commonly known as the Reclamation Act, together with subsequent, supplementary and amendatory acts on the part of the United States, and an act of the Legislature, Chapter 87, General Laws of Oregon, 1913, on the part of the State of Oregon. The Reclamation Act is well known and will not be repeated here. Copies of the Reclamation Act and amendments may be secured by application to the U. S. Reclamation Service, Washington, D. C. The State law authorizing this work was quoted in the Deschutes Report published in 1914, and need not be given here.

AGREEMENTS

Agreement May 5, 1913.—Under authority of these acts of Congress and of the State Legislature an agreement was entered into between the United States and the State of Oregon through the Secretary of the Interior, Franklin K. Lane, and the State Engineer, John H. Lewis, under date of May 5, 1913, which provides for the manner of carrying on the investigations. This agreement is given in full in the Deschutes Report, which can be obtained on application to the U. S. Reclamation Service or to the State Engineer, and will not be repeated here. In general this agreement provides:

1. That surveys and investigations for irrigation projects, with incidental power possibilities, be made in Central Oregon.
2. That from time to time during the investigations withdrawals of public lands and of unappropriated waters be made by the Secretary of the Interior and the State Engineer respectively, as may appear in their judgment advisable to protect the development of any project proposed for irrigation.
3. That all investigations be made under plans agreed upon by the Reclamation Service and the State Engineer.
4. That the field notes and data acquired or prepared be filed with the Reclamation Service, accessible at all times to the State Engineer or his representatives.
5. That on completion of the investigations, a report be published with conclusions and recommendations.
6. That the expense of the work be equally divided between the United States and the State of Oregon.
7. That employees paid by the United States and the State

Digitized by Google

shall be subject to rules and regulations established by each respectively, and that in the selection of employees preference be given to residents of the state.

Supplementary Agreements.—As contemplated under the agreement of May 5, 1913, a supplementary agreement as to surveys and investigations for the season of 1914 was entered into, providing for the investigations and report on irrigation possibilities in Crooked River basin, also on the Silver Lake Project, John Day Project ,Malheur Project and Owyhee Project.

ORGANIZATION

Field surveys and office studies on which this report is based have been made by State and Federal engineers, under the direction of John T. Whistler, Engineer, U. S. Reclamation Service, and conform to the general plan specified under supplementary agreements between the Reclamation Service and the State. The report has been prepared under direction of John T. Whistler in conference with John H. Lewis, and is subscribed to by them on behalf of the co-operating Federal and State authorities. Attention is directed to the fact that the subscription to this report by officers of the Reclamation Service and the State does not commit other officials of the Government or of the State to the conclusions reached herein.

Field work for this report was done by W. R. Parkhill, with the exception of the soundings of Silver Lake, which were taken by Paul V. Hodges, engineer in the U. S. Geological Survey.

Office studies and computations for this report have been made by W. R. Parkhill, assisted by Joseph Weare. D. S. Hays assisted in computations relating to power development and pumping. The report itself has been largely written by Mr. Parkhill.

The soil survey was made by W. L. Powers, Assistant Professor of Irrigation and Drainage, Oregon Agricultural College.

Use has been made of all available topography obtained during earlier investigations of the U. S. Reclamation Service, also of topography and information given in Water Supply Paper No. 220, Geology and Water Resources of a portion of south-central Oregon, by Gerald A. Waring, 1908.

LOCATION AND GENERAL DESCRIPTION

The Silver Lake Basin and Fort Rock Valley to the north are depressions in the general level of the high plateau in the south-central part of Oregon. For location see Sheet No. 38. The general elevation is 4,500 feet above sea level.

Silver Lake basin in its lowest depression at the southern end contains Silver Lake, a shallow body of fresh water covering about 16 square miles. The eastern and western borders of the lake are formed by abrupt cliffs rising to a height of about 600

Digitized by Google

feet above the lake. On the south the land rises with a generally even slope to the northern end of Winter Ridge, locally known as Rimrock Mountains. This slope is rocky, much cut by gulleys, and not suitable to agricultural development.

Paulina Marsh, covering about the same area as Silver Lake, occupies the northern portion of the basin and is but a few feet higher in elevation than Silver Lake.

Bordering Paulina Marsh to the south and west are the gently sloping lands which may be most easily developed by irrigation from streams entering the basin. Three streams, Silver, Bridge and Buck Creeks, draining the timbered slopes to the south and west, on reaching this slope above Paulina Marsh, spread out and water the present hay lands bordering the marsh. In years of moderate and high run-off, the waters from these streams find their way from Paulina Marsh, either by overflow or under drainage, to Silver Lake where evaporation keeps the lake at a fairly constant elevation. In periods of extreme high run-off, the lake has been known to overflow into Thorn Lake to the northeast through a gap connecting Silver Lake basin with Fort Rock Valley.

Fort Rock Valley lies to the northeast of Paulina Marsh and is separated from it by the Conley Hills, which terminate at their southeastern end in Table Rock, a picturesque flat topped mountain to the north of Silver Lake. Fort Rock Valley is about five miles wide and twenty miles long, reaching from Fort Rock on the northwest to Thorn Lake and Seven Mile Ridge on the Southeast.

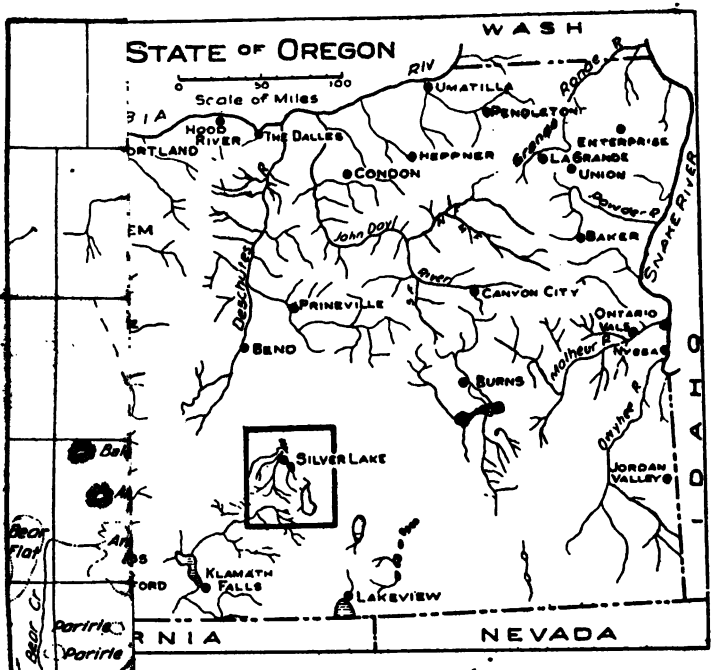
Christmas Lake Valley lies to the east of Seven Mile Ridge and extends to Pine Ridge on the east. This valley is very similar in character to Fort Rock Valley and a few feet lower in elevation. In its lowest depression it contains Christmas Lake, which is fifteen feet lower than Silver Lake.

Silver Lake basin, Fort Rock Valley and Christmas Lake Valley undoubtedly at some time have formed the bed of an ancient lake, covering about 300 square miles. With the exception of Paulina Marsh and the depressions containing Silver Lake, Thorn Lake and Christmas Lake, the bottom of this old lake bed is comparatively level and covered generally with a growth of sage-brush and greasewood.

Sand ridges form a prominent feature of the topography of the eastern part of Fort Rock Valley, and also parts of Christmas Lake Valley. East of Fossil Lake and Sand Springs, shifting sand dunes reach for many miles to Pine Ridge on the east.

With the exception of Pine Ridge, the high plateau country to the east and south of Christmas Lake Valley is barren of vegetation except for scattering sagebrush and a few junipers on the ridges. North and west of the valleys are the higher slopes of the Paulina Mountains and the Walker Range, covered

Digitized by Google



LVER LAKE PROJECT

RATIVE WORK
and State of Oregon
LAKE
Proposed Project
Date
6-1915
6-
6-
6-11
ject File No. 38

Digitized by Google

Digitized by Google

with valuable pine timber, a large part of which is in the Deschutes and Paulina National Forests. South of Paulina Marsh and west of Summer Lake to Yamsay Mountain are the timbered mountains and valleys which furnish practically all of the run-off to Paulina Marsh.

Settlement.—The first settlements in these valleys came about 1868 at the close of the Shoshone Indian War, and were made in the Silver Lake Basin where wild hay meadows offered food for stock. Trips had been made through the valleys in earlier times by traders and exploring expeditions, on one of which, in the late fall of 1843, Col. John C. Fremont crossed Lake County. Summer Lake and Winter Ridge, were so named by him from the contrast in temperature noted when the expedition descended the steep bluff from the mountains west of the lake, where they had encountered heavy snow. The valley below was green and protected from cold winds.

In the early sixties gold was discovered in the John Day and Powder River regions, and led to the traversing of these valleys by prospectors. One of these expeditions, coming through Sycan Marsh from Fort Klamath in 1861, found Paulina Marsh to be practically a lake almost to the site of the present town of Silver Lake. The scout for the party is reported to have gone north to the west end of Fort Rock Valley. Finding this also submerged, the party turned eastward and rounded the south side of Silver Lake. The road which they built along the steep bluff on the east side of Silver Lake may still be seen. The present channel connecting Silver Lake with Christmas Lake Valley, or the Low Desert, was probably eroded to its present depth at that time.

About 1875 a post-office was established on the west shore of Silver Lake and remained until the town of Silver Lake was established at its present site in 1886. Silver Lake has about 160 inhabitants, is the principal trading center for the entire valley, and had the only post-office in the region until about 1905, when homesteads began to be taken up in Christmas Lake Valley near Fossil Lake and post-offices were secured at Cliff and at Lake. Since that time filing on homesteads has been rapid, until now nearly all of the valley lands are taken. Fort Rocks, a village of about 50 inhabitants, was settled in 1908, and is located but a short distance from the butte, Fort Rock, the striking scenic feature of this valley. See Plate No. 1.

Transportation and Markets.—The principal industry is stock raising. The limited amounts of grains and grain hays are sold locally, and a great deal of wild hay is raised for winter feeding. Practically no farm produce from these valleys is sold outside on account of the great distance to market and the local demand for the entire amount of such farm products as are raised.

Wool is shipped to some extent, but this has to be hauled by wagon ninety miles to Bend, the most convenient shipping point.

Digitized by Google

and the present terminus of the Oregon Trunk Railroad and the Deschutes Branch of the Oregon-Washington Railroad & Navigation Company. These are branch lines in the Deschutes Valley of the main lines down the Columbia River. Kirk, the present terminus of the Klamath Falls branch of the Southern Pacific Railroad, is seventy miles southwest of Silver Lake, but though nearer than Bend it is not used to any great extent because of poor roads. Stock from Sycan Marsh is driven to Klamath Falls, a distance of about seventy-five miles.

Lakeview, 104 miles southeast of Silver Lake, is the terminus of the Nevada, California & Oregon Railroad, which connects with the main line of the Central Pacific at Reno, Nevada, and the Western Pacific at Doyle, Nevada.

The Oregon Eastern Railroad, a branch of the Union Pacific system, has been recently constructed from Ontario, Oregon, to Riverside, in Malheur County. It is now being extended to Harriman in Harney County. The location survey of this line extends westward through the Christmas Lake and Fort Rock Valleys to connect with the partly completed Natron cut-off from near Eugene to Klamath Falls, and with the extension southward of the Deschutes branch of the Oregon-Washington Railroad & Navigation Company.

Digitized by Google

GENERAL INFORMATION RELATING TO THE PROJECT

CLIMATE

The climate in the Silver Lake and Fort Rock region is similar to that of the Upper Deschutes basin. The summer days are generally clear and warm and the nights cool; light frosts may occur any night of the summer months. Westerly winds usually bring cooler temperatures and often light rains in May and June. Prevailing winds are from the northwest in the summer and from the south in winter. Northeasterly winds are hot in summer and cold in winter. Fall weather is characterized by calm nights and mornings, usually followed by strong northwesterly winds in the latter part of the day.

Temperature and Rainfall.—The greater part of the precipitation comes from October to March in the form of snow which usually lies all winter on the higher timbered mountain slopes and disappears after each snow storm in the open valleys. The summers are relatively dry, most of the rainfall occurring in May and June, after which but very little can be expected. Records of temperature and precipitation have been kept at Silver Lake* continuously since 1889, and at Christmas Lake or Cliff since 1907. Precipitation records have been kept at Fort Rock since 1909.

In the following tables, temperatures and precipitation for the two stations, Silver Lake and Cliff, have been compiled from data obtained from Weather Bureau records. Precipitation data for Fort Rock have been obtained through the editor of the Fort Rock Times, the records from November 1, 1909, to October 31, 1914, having been kept by Mr. J. T. Rhoton.

*Station established by the Signal Service, October, 1889.

Digitized by Google

Climatological Data 1907—1915. JANUARY.

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	18.2	58	1, 2	—19	14	56	1.11	0.77	.....	2
1908	Silver Lake	29.6	50	1, 11, 15	2	28	37	0.00	.00	0.0	0
	*Christmas Lake	26.2	52	11	—18	21	38	0.92	.30	7.0	4
1909	Silver Lake	32.0	58	15	—12	11	41	3.50	.55	9.5	14
	*Christmas Lake	29.4	49	16	—20	12	37	2.34	.50	16.5	13
1910	Silver Lake	25.6	52	23	—17	3	36	2.65	.40	27.5	10
	*Christmas Lake	23.6	52	23	—20	3	47	0.37	.10	5.0	9
	Fort Rock	.....	.....	.....	.....	.....	.....	1.05	.30	9.1	9
1911	Silver Lake	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Cliff	25.8	67	6	—11	23	53	0.68	.16	8.5	9
	Fort Rock	.....	.....	.....	.....	.....	.....	1.15	.35	11.0	8
1912	Silver Lake	30.0	50	22	—18	3	51	0.92	.57	0.5	7
	Cliff	29.6	48	14, 31	—20	3	55	1.34	.36	5.0	19
	Fort Rock	.....	.....	.....	.....	.....	.....	1.18	.50	9.8	12
1913	Silver Lake	24.6	47	24	—11	6	33	1.37	.40	11.0	9
	Cliff	22.6	47	29, 30, 31	—21	6	47	0.67	.15	13.0	9
	Fort Rock	.....	.....	.....	.....	.....	.....	1.17	.50	15.5	9
1914	Silver Lake	32.4	54	4	11	12	29	2.59	.70	17.0	12
	Cliff	36.6	67	6	6	19	39	1.01	.20	15.5	12
	Fort Rock	.....	.....	.....	.....	.....	.....	2.32	.55	26.5	11
1915	Silver Lake	24.2	48	3	—12	23	46	0.43	.12	1.0	7
	Cliff	25.2	59	30	—14	22	49	0.21	.10	5.5	4
	Fort Rock	.....	.....	.....	.....	.....	.....	0.31	.10	T	4
Mean	Silver Lake	27.08	.....	.....	.....	.....	.....	1.57	.....	.....	7.6
	Cliff	27.38	.....	.....	.....	.....	.....	0.94	.....	.....	9.9
	Fort Rock	.....	.....	.....	.....	.....	.....	1.20	.....	.....	8.8

*Christmas Lake was name applied to observation taken at Cliff P. O. until May, 1911, when it was changed to Cliff.

Digitized by Google

FEBRUARY

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	39.4	66	15	17	15	49	2.04	0.56	.....	7
1908	Silver Lake	35.2	70	23	5	2	45	0.09	0.05	0.5	2
	Christmas Lake	30.8	60	26	0	3	38	0.14	0.05	2.0	4
	Silver Lake	34.1	50	24, 28	4	8	30	0.98	0.15	5.3	12
1909	Christmas Lake	32.0	52	2, 16	—4	8	39	0.58	0.24	5.0	7
	Silver Lake	30.7	52	12, 28	—8	3	36	1.96	0.67	8.0	9
1910	Christmas Lake	29.0	50	28	—14	3	42	0.97	0.20	4.0	10
	Fort Rock	.....	.....	.....	.....	.....	.....	1.28	0.47	7.3	7
1911	Silver Lake	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Cliff	19.9	41	9	—11	15	47	0.13	0.06	3.1	4
	Fort Rock	.....	.....	.....	.....	.....	.....	0.44	0.30	6.5	3
1912	Silver Lake	34.1	52	27	8	25	37	0.22	0.09	0.0	3
	Cliff	33.7	48	7,9,13,26,27	5	25	37	0.89	0.18	T	10
	Fort Rock	.....	.....	.....	.....	.....	.....	0.22	0.08	1.0	4
1913	Silver Lake	28.8	58	15, 16	—3	22	37	0.39	0.28	4.0	2
	Cliff	28.4	57	16	—7	28	47	0.13	0.10	3.0	2
	Fort Rock	.....	.....	.....	.....	.....	.....	0.07	0.05	1.2	2
1914	Silver Lake	32.3	55	28	3	3	36	0.39	0.18	0.0	3
	Cliff	36.3	68	28	0	3	49	0.68	0.12	1.0	10
	Fort Rock	.....	.....	.....	.....	.....	.....	0.36	0.12	.....	6
1915	Silver Lake	31.6	53	14	11	16	37	1.86	0.73	5.5	8
	Cliff	34.0	68	5	8	14	42	1.20	0.38	9.0	7
	Fort Rock	.....	.....	.....	.....	.....	.....	1.41	0.28	T	9
Mean	Silver Lake	33.3	.....	.....	.....	.....	.....	0.99	.....	.....	5.8
	Cliff	30.5	.....	.....	.....	.....	.....	0.59	.....	.....	6.8
	Fort Rock	.....	.....	.....	.....	.....	.....	0.63	.....	.....	5.2

Digitized by Google

MARCH

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	36.0	58	6	8	12	34	3.23	0.80	8.0	9
1908	Silver Lake	35.2	64	23	8	6	46	0.27	0.20	2.0	2
	Christmas Lake	35.0	61	15, 24	—3	4	40	0.45	0.22	4.0	5
1909	Silver Lake	37.2	70	16	10	20	58	1.07	0.52	T	5
	Christmas Lake	36.2	65	16	7	18	42	0.60	0.20	1.0	8
1910	Silver Lake										
	Christmas Lake	47.0	66	13	14	29	44	0.43	0.32	0.0	5
	Fort Rock							0.32	0.25	0.0	3
1911	Silver Lake										
	Cliff	38.4	78	31	—7	1	56	0.06	0.04	0.0	2
	Fort Rock							0.15	0.10	0.0	3
1912	Silver Lake	34.3	68	31	7	3	55	0.92	0.22	2.0	6
	Cliff	32.1	64	31	5	2, 21	56	0.39	0.08	1.0	0
	Fort Rock							0.76	0.35	10.0	10
1913	Silver Lake	35.8	64	9	10	24, 26	38	0.10	0.10	T	1
	Cliff	34.0	63	9	—3	14	43	0.26	0.06	0.5	7
	Fort Rock							0.17	0.09	1.6	2
1914	Silver Lake	42.0	77	20	13	26, 28	52	0.18	0.14		2
	Cliff	45.2	84	17	4	26	66	0.04	0.02	0.5	2
	Fort Rock							0.09	0.06		2
1915	Silver Lake	41.9	75	22	15	8	50	0.62	0.32	0.5	3
	Cliff	38.0	72	22	15	24, 25	55	1.34	0.38	4.5	6
	Fort Rock							0.49	0.16	1.0	8
Mean	Silver Lake	37.4						0.91			4.0
	Cliff	37.6						0.45			5.4
	Fort Rock							0.33			4.7

Digitized by Google

APRIL

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	46.5	74	13	10	4, 7	53	0.52	0.52	0.0	1
1908	Silver Lake										
	Christmas Lake	42.8	77	11	9	4	57	0.56	0.27		5
1909	Silver Lake	41.9	70	11,15,24,25,26	12	7, 9	52	0.10	0.10	T	1
	Christmas Lake	38.4	70	25	6	18	60	0.07	0.06	T	2
1910	Silver Lake										
	Christmas Lake	46.6	85	23	11	14	58	0.34	0.22	0.0	4
	Fort Rock							0.26	0.14	0.0	3
1911	Silver Lake	41.6	77	24	12	14	51	1.41	0.44		8
	Cliff	39.2	76	24	10	11,13,14	51	0.37	0.18	1.0	5
	Fort Rock							0.61	0.30	2.5	6
1912	Silver Lake	40.4	72	9	15	14	50	1.34	0.55	3.0	8
	Cliff	38.5	71	9	11	5, 13	54	1.39	0.31	4.0	11
	Fort Rock							1.34	0.65	7.4	6
1913	Silver Lake	42.8	74	24	15	28	46	0.90	0.30	4.0	5
	Cliff	40.2	75	25	10	23	50	0.70	0.22	3.5	6
	Fort Rock							0.69	0.25	4.75	6
1914	Silver Lake	43.3	71	14, 18	19	28	46	1.14	0.29	0.0	10
	Cliff	48.8	84	18	17	17	61	1.73	0.44	0.5	12
	Fort Rock							0.67	0.30	0.0	5
1915	Silver Lake	48.2	84	28	19	14	53	0.23	0.23	0.0	1
	Cliff	42.8	80	28	13	15	58	0.60	0.25	0.0	5
	Fort Rock							0.49	0.23	0.0	4
Mean	Silver Lake	43.5						0.80			4.9
	Cliff	42.1						0.72			6.2
	Fort Rock							0.68			5.0

Digitized by Google

MAY

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	48.0	74	31	14	2	58	2.17	0.92	.....	7
1908	Silver Lake	46.2	83	13	15	10	65	0.37	0.22	0.0	4
	Christmas Lake	42.2	75	5	8	13	56	0.72	0.34	0.0	5
1909	Silver Lake	47.4	86	31	17	5	50	0.34	0.13	T	4
	Christmas Lake	43.4	85	31	9	12	57	0.09	0.03	0.0	4
1910	Silver Lake	55.3	96	31	22	15	57	0.58	0.20	.....	5
	Christmas Lake	51.2	93	31	20	19	61	0.70	0.32	.....	7
	Fort Rock	.....	.....	.....	.....	.....	.....	0.23	0.12	.....	4
1911	Silver Lake	46.6	78	21, 30	22	6	49	0.82	0.20	.....	9
	Cliff	43.8	76	30	13	25	53	0.64	0.23	0.0	7
	Fort Rock	.....	.....	.....	.....	.....	.....	0.56	0.15	1.0	7
1912	Silver Lake	48.9	80	14	23	3	48	1.44	0.32	0.0	8
	Cliff	47.0	78	14	16	23	49	2.12	0.45	0.0	12
	Fort Rock	.....	.....	.....	.....	.....	.....	1.45	0.37	1.0	9
1913	Silver Lake	51.4	85	26, 31	15	3	50	0.96	0.45	.....	5
	Cliff	48.9	85	26	10	1	53	0.85	0.58	0.0	3
	Fort Rock	.....	.....	.....	.....	.....	.....	0.84	0.42	.....	5
1914	Silver Lake	55.0	89	31	27	1	51	2.09	0.50	.....	8
	Cliff	54.6	98	30	9	4	64	1.53	0.33	0.0	9
	Fort Rock	.....	.....	.....	.....	.....	.....	1.70	0.30	0.0	10
1915	Silver Lake	45.2	73	31	20	2	44	0.77	0.33	0.0	5
	Cliff	45.4	77	7	18	2.5	52	1.03	0.26	0.0	10
	Fort Rock	.....	.....	.....	.....	.....	.....	0.93	0.25	T	11
Mean	Silver Lake	49.3	.....	.....	.....	.....	.....	1.06	.....	.....	6.1
	Cliff	47.0	.....	.....	.....	.....	.....	0.96	.....	.....	7.1
	Fort Rock	.....	.....	.....	.....	.....	.....	0.95	.....	.....	7.7

Digitized by Google

JUNE

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	54.2	89	3, 19, 30	25	24	55	0.89	0.42	.....	6
1908	Silver Lake	57.3	94	29	30	8, 17, 21, 23, 26	63	2.08	0.75	0.0	5
	Christmas Lake	50.8	87	24	21	2	56	0.92	0.39	T	4
1909	Silver Lake	57.6	87	1	30	6, 7	49	1.43	0.52	0.0	4
	Christmas Lake	53.8	89	1	20	8	54	0.67	0.33	0.0	6
1910	Silver Lake	.....	.....	.....	.....	.....	.....	0.88	0.57	.....	3
	Christmas Lake	54.4	90	25, 26	19	21	57	0.63	0.40	0.0	3
	Fort Rock	.....	.....	.....	.....	.....	.....	0.73	0.50	.....	4
1911	Silver Lake	57.4	89	11	20	4	51	1.04	0.35	0.0	8
	Cliff	55.1	89	11	15	4	53	1.78	1.13	0.0	7
	Fort Rock	.....	.....	.....	.....	.....	.....	1.40	0.82	.....	4
1912	Silver Lake	56.8	89	5	27	15	52	1.97	0.64	.....	9
	Cliff	55.4	89	5	23	15	51	1.21	0.54	0.0	4
	Fort Rock	.....	.....	.....	.....	.....	.....	1.43	0.75	.....	6
1913	Silver Lake	55.8	87	1	27	20	48	1.69	0.62	.....	9
	Cliff	54.2	84	1	23	20	50	3.61	0.84	.....	11
	Fort Rock	.....	.....	.....	.....	.....	.....	2.43	0.70	.....	12
1914	Silver Lake	55.3	94	17	23	6	52	0.43	0.17	0.0	3
	Cliff	55.0	93	15	14	5	57	2.58	1.58	0.5	8
	Fort Rock	.....	.....	.....	.....	.....	.....	0.27	0.12	0.0	3
1915	Silver Lake	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Cliff	50.6	86	30	19	19	54	0.11	0.06	0.0	2
	Fort Rock	.....	.....	.....	.....	.....	.....	0.07	0.06	0.0	2
Mean	Silver Lake	56.3	.....	.....	.....	.....	.....	1.30	.....	.....	5.9
	Cliff	53.7	.....	.....	.....	.....	.....	1.44	.....	.....	5.62
	Fort Rock	.....	.....	.....	.....	.....	.....	1.06	.....	.....	5.17

Digitized by Google

JULY

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lak	69.1	98	30	35	5	56	0.51	0.31	0.0	3
1908	Silver Lake	67.2	105	29	31	17	70	0.80	0.33	0.0	4
	Christmas Lake	63.6	101	30	28	6	64	0.33	0.18	0.0	3
1909	Silver Lake	60.4	92	3, 21	25	18	54	0.43	0.20	0.0	4
	Christmas Lake	57.2	93	2	20	18	56	0.60	0.35	0.0	5
1910	Silver Lake							0.70	0.43	0.0	2
	Christmas Lake	63.8	97	13	30	5	55	0.66	0.37	0.0	3
	Fort Rock							0.23	0.15	0.0	4
1911	Silver Lake	66.4	99	16	28	8	56	0.16	0.10	0.0	3
	Cliff	63.0	97	15	25	8	55	0.42	0.17	0.0	3
	Fort Rock							0.11	0.11	.....	1
1912	Silver Lake	61.6	95	16	31	1	54	0.76	0.21	0.0	6
	Cliff	58.5	94	16, 17	28	3	57	0.59	0.33	0.0	4
	Fort Rock							0.63	0.30	.....	4
1913	Silver Lake	61.2	94	20	29	17	45	1.84	1.10	0.0	4
	Cliff	59.8	91	18	25	13	52	1.17	0.72	0.0	4
	Fort Rock							0.89	0.45	.....	3
1914	Silver Lake	65.1	95	18, 19	29	21	55	0.32	0.25	0.0	2
	Cliff	60.6	93	18	23	21	55	0.13	0.08	0.0	2
	Fort Rock							1.48	0.90	0.0	5
1915	Silver Lake	63.4	99	1	27	17	56	1.36	0.58	0.0	5
	Cliff	57.3	97	23	19	17	62	1.20	0.56	0.0	5
	Fort Rock	.....	.....	.....	.....	.....	.....	2.46	0.90	0.0	5
Mean	Silver Lake	64.3	.....	.....	.....	.....	.....	0.76	.....	.....	3.7
	Cliff	60.5	.....	.....	.....	.....	.....	0.64	.....	.....	3.7
	Fort Rock	.....	.....	.....	.....	.....	.....	0.97	.....	.....	3.7

Digitized by Google

AUGUST

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	59.0	98	6	21	27	49	1.23	1.01	0.0	3
1908	Silver Lake	61.3	100	1, 7	20	25	66	0.18	0.14	0.0	2
	Christmas Lake	58.5	98	8	15	30	63	0.12	0.12	0.0	1
1909	Silver Lake	61.8	96	19	26	26	58	0.0	0.0	0.0	0
	Christmas Lake	57.8	96	19	18	27	65	0.0	0.0	0.0	0
1910	Silver Lake	57.8	91	8	23	29	57	0.0	T	0.0	0
	Christmas Lake	56.1	91	19, 25	18	29	66	0.0	0.0	0.0	0
	Fort Rock	.....	.....	.....	.....	.....	.....	0.0	0.0	0.0	0
1911	Silver Lake	61.0	91	9	29	20	53	T	T	0.0	0
	Cliff	57.0	90	30	24	20	58	0.18	0.15	0.0	2
	Fort Rock	.....	.....	.....	.....	.....	.....	0.05	0.05	0.0	1
1912	Silver Lake	60.6	91	24	31	31	48	1.45	0.49	0.0	6
	Cliff	57.0	92	23	23	30	55	0.98	0.30	.....	8
	Fort Rock	.....	.....	.....	.....	.....	.....	0.64	0.15	.....	6
1913	Silver Lake	65.2	94	24	28	18	53	1.10	0.75	0.0	2
	Cliff	61.5	94	24	20	18	61	0.65	0.16	0.0	6
	Fort Rock	.....	.....	.....	.....	.....	.....	0.85	0.35	.....	3
1914	Silver Lake	64.2	98	2, 13	28	19	56	T	T	0.0	0
	Cliff	59.4	95	1, 2	20	17	59	0.0	0.0	0.0	0
	Fort Rock	.....	.....	.....	.....	.....	.....	0.37	0.22	.....	3
1915	Silver Lake	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Cliff	65.0	100	29	35	31	60	T	T	0.0	0
	Fort Rock	.....	.....	.....	.....	.....	.....	0.03	0.02	0.0	2
Mean	Silver Lake	61.3	.....	.....	.....	.....	.....	0.50	.....	.....	1.6
	Cliff	59.0	.....	.....	.....	.....	.....	0.09	.....	.....	3.2
	Fort Rock	.....	.....	.....	.....	.....	.....	0.32	.....	.....	2.5

Digitized by Google

SEPTEMBER

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	56.1	95	9	23	12,21,24	63	0.87	0.50	0.0	4
	Christmas Lake	50.6	92	24	17	13	69	0.39	0.39	0.0	1
1908	Silver Lake	54.8	93	5, 6	14	24, 25	66	0.45	0.35	0.0	2
	Christmas Lake	52.4	90	4	9	25	61	0.78	0.40	0.0	2
1909	Silver Lake	55.3	89	15, 16	22	24	53	0.84	0.50	0.0	6
	Christmas Lake	50.8	86	16	15	22	59	0.89	0.37	0.0	7
1910	Silver Lake										
	Christmas Lake	49.8	82	5	14	7, 11	61	0.90	0.37	0.0	6
	Fort Rock							1.24	0.50	0.0	5
1911	Silver Lake	49.6	84	1	19	18	53	1.51	0.65	0.0	4
	Cliff	47.8	84	1	13	18	58	1.31	0.35	0.0	8
	Fort Rock							2.04	0.70	0.0	5
1912	Silver Lake	53.2	82	26	23	14,20,23	52	0.46	0.31	0.0	2
	Cliff	48.0	82	18	14	24	59	0.58	0.24	0.0	5
	Fort Rock							0.27	0.12		4
1913	Silver Lake	56.8	91	20, 21	20	26	57	0.07	0.07	0.0	1
	Cliff	51.0	89	7	13	23	61	0.36	0.36	0.0	1
	Fort Rock							0.03	0.03		1
1914	Silver Lake	51.1	87	1	22	9	58	0.54	0.32	0.0	3
	Cliff	48.9	82	2, 10	14	12, 13	67	1.41	0.39	0.0	10
	Fort Rock							0.94	0.46		5
1915	Silver Lake										
	Cliff	48.8	87	18	15	28, 29	61	0.15	0.15	0.0	1
	Fort Rock							T	T	0.0	0
Mean	Silver Lake	53.8						0.68			3.1
	Cliff	49.8						0.75			4.5
	Fort Rock							0.75			3.3

Digitized by Google

OCTOBER

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	50.0	80	15, 20	22	13,26,31	55	0.77	0.35	0.0	8
	Christmas Lake	49.0	81	5	14	2	58	0.15	0.13	0.0	2
1908	Silver Lake	43.7	82	8	12	22	59	1.31	0.60	0.0	4
	Christmas Lake	42.2	81	8	16	4,21,22	56	1.41	0.85	T	5
1909	Silver Lake	51.0	80	11	19	23	55	0.65	0.20	0.0	6
	Christmas Lake	44.2	81	10	12	27	56	0.74	0.21	0.0	9
1910	Silver Lake	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Christmas Lake	44.8	81	8	10	27	58	0.33	0.25	0.0	3
	Fort Rock	.....	.....	.....	.....	.....	.....	0.30	0.19	0.0	2
1911	Silver Lake	44.5	74	7	13	27	49	0.72	0.43	0.0	2
	Cliff	41.4	79	7	6	27	53	0.51	0.24	0.0	4
	Fort Rock	.....	.....	.....	.....	.....	.....	0.52	0.25	0.0	4
1912	Silver Lake	41.1	78	1	9	30	53	0.22	0.22	0.0	1
	Cliff	38.2	72	3, 13, 14	6	21	62	0.26	0.12	0.0	3
	Fort Rock	.....	.....	.....	.....	.....	.....	0.24	0.13	1	3
1913	Silver Lake	.....	.....	.....	15	10	.....	0.08	0.08	0.0	1
	Cliff	.....	.....	.....	8	4, 25	.....	0.31	0.16	0.0	2
	Fort Rock	.....	.....	.....	.....	.....	.....	0.11	0.11	.....	1
1914	Silver Lake	47.2	82	13	18	22	54	1.17	0.60	0.0	5
	Cliff	43.1	78	13	17	22, 25	50	1.10	0.30	0.0	7
	Fort Rock	.....	.....	.....	.....	.....	.....	1.07	0.75	.....	4
Mean	Silver Lake	46.2	.....	.....	.....	.....	.....	0.70	.....	.....	3.9
	Cliff	43.3	.....	.....	.....	.....	.....	0.60	.....	.....	4.4
	Fort Rock	.....	.....	.....	.....	.....	.....	0.48	.....	.....	2.8

Digitized by Google

NOVEMBER

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	38.3	73	9	11	20	56	0.38	0.18	0.0	4
	Christmas Lake	34.7	66	8	5	3	56	0.28	0.09	T	5
1908	Silver Lake	39.0	72	8	10	28	57	0.30	0.20	T	2
	Christmas Lake	35.9	70	6	2	24	55	0.10	0.08	.....	2
1909	Silver Lake	38.6	70	3	—4	15	.....	3.28	0.85	1.0	10
	Christmas Lake	40.4	66	3	—12	15	44	2.50	0.57	4.5	16
1910	Silver Lake	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Christmas Lake	34.6	68	1	—11	26	53	2.93	0.49	9.5	73
	Fort Rock	.....	.....	.....	.....	.....	.....	3.40	0.94	11.5	10
1911	Silver Lake	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Cliff	33.2	65	3	—11	11	52	0.41	0.33	0.5	3
	Fort Rock	.....	.....	.....	.....	.....	.....	0.52	0.27	1.0	3
1912	Silver Lake	39.1	66	13	9	24, 29	48	0.88	0.50	0.0	4
	Cliff	36.4	57	12, 27	5	24, 29	49	0.96	0.30	0.0	6
	Fort Rock	.....	.....	.....	.....	.....	.....	0.54	0.38	0.0	4
1913	Silver Lake	38.7	75	1, 4	11	21	55	1.40	0.27	T	9
	Cliff	39.5	68	7	11	3, 21	47	1.40	0.35	2.0	10
	Fort Rock	.....	.....	.....	.....	.....	.....	1.36	0.55	4.5	7
1914	Silver Lake	38.8	68	4	6	21	50	0.25	0.15	1.0	2
	Cliff	33.0	61	4, 8	—1	21	56	0.11	0.11	T	1
Mean	Silver Lake	38.8	.....	.....	.....	.....	.....	1.08	.....	.....	5.2
	Cliff	36.0	.....	.....	.....	.....	.....	1.09	.....	.....	7.0
	Fort Rock	.....	.....	.....	.....	.....	.....	1.45	.....	.....	6.0

Digitized by Google

DECEMBER

Year.	Station.	Temperature—Degrees Fahrenheit.						Precipitation—Inches.			
		Mean for Month.	Max.	Date.	Min.	Date.	Greatest Daily Range.	Total for Month.	Greatest in 24 Hours	Total Unmelted Snow.	.01 or more No. of Days.
1907	Silver Lake	33.6	55	4	8	15, 16	41	2.10	0.70	5.5	8
	Christmas Lake	31.4	59	3	—1	16	45	2.39	1.10	8.0	7
1908	Silver Lake	27.6	52	26	—16	17	43	0.40	0.15	4.0	3
	Christmas Lake	25.1	47	25	—20	18	50	0.28	0.11	3.0	3
1909	Silver Lake	25.4	46	11, 12	—6	6	37	0.70	0.20	8.0	5
	Christmas Lake	21.8	44	8, 9, 12, 18	—16	6	44	1.01	0.50	15.0	9
1910	Silver Lake										
	Christmas Lake	30.6	53	1	3	22	38	0.86	0.25	2.0	8
	Fort Rock							0.42	0.17		3
1911	Silver Lake	26.8	52	1, 4, 12, 14	—15	21	55	0.43	0.10	1.5	6
	Cliff	25.4	54	1	—6	21	51	0.54	0.26	3.0	3
	Fort Rock							0.16	0.05	3.0	4
1912	Silver Lake	26.9	56	11	—2	27	43	1.88	0.60	15.0	6
	Cliff	25.8	50	11	—6	26	51	0.44	0.17	2.0	7
	Fort Rock							1.09	0.21	8.2	8
1913	Silver Lake	29.4	58	13	4	9	39	1.32	0.90	1.5	4
	Cliff	30.2	72	7	—6	18	60	0.85	0.35	11.0	7
	Fort Rock							1.20	0.75	6.8	5
1914	Silver Lake	21.1	52	10	—15	14	46	0.18	0.18	2.0	1
	Cliff	17.4	45	1	—21	18, 21	46	0.20	0.10	3.0	3
Mean	Silver Lake	27.2						1.00			4.7
	Cliff	26.0						0.82			5.9
	Fort Rock							0.72			5.0

Digitized by Google

RAINFALL RECORD AT SILVER LAKE, OREGON*

Precipitation in Inches

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1889	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.48	1.31	.....
1890	1.03	2.74	1.04	0.34	.....	.....	.....	.....	.....	.....	.....	Tr.	.....
1891	0.62	3.08	0.77	1.46	2.65	2.24	1.63	.....	.....	.....	1.50	1.46	.....
1892	0.12	0.91	2.40	0.77	2.52	.....	.....	.....	.....	.....	.....	.....	.....
1893	1.50	0.75	1.09	0.93	.....	.....	.....	.....	.....	.....	.....	.....	.....
1894	.....	.....	.....	.....	.....	0.82	.....	.....	.....	.....	.....	.....	.....
1895	.....	.....	.....	1.89	0.64	0.30	0.13	0.39	0.18	0.49	2.32	.....	.....
1896	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1897	0.25	.....	0.80	0.25	1.91	2.65	0.07	0.00	0.39	0.23	0.13	1.47	.....
1898	0.27	0.30	0.15	0.22	1.87	0.76	0.20	0.05	0.20	0.56	2.03	0.38	6.99
1899	1.40	0.24	2.57	1.02	0.49	Tr.	0.00	0.40	0.37	1.44	0.75	1.68	10.36
1900	0.80	Tr.	0.31	0.53	0.90	0.42	Tr.	0.45	0.49	2.09	0.40	0.95	7.34
1901	0.08	1.69	0.30	0.10	0.34	0.04	.....	.....	1.09	1.31	0.57	.....	.....
1902	0.24	1.45	0.25	2.27	0.67	Tr.	.....	.....	.....	.....	.....	2.16	.....
1903	1.73	0.55	1.15	.....	0.52	0.72	.....	.....	.....	.....	.....	.....	.....
1904	.....	.....	.....	0.98	0.65	0.54	1.60	0.00	.....	0.56	0.55	.....	.....
1905	.....	.....	1.03	0.70	1.48	2.33	0.05	0.00	1.34	0.55	0.23	0.07	.....
1906	1.98	0.55	1.89	0.38	2.18	1.08	0.64	0.78	.....	.....	0.42	1.68	.....
1907	1.11	2.04	3.23	0.52	2.17	0.80	0.51	1.23	0.87	0.77	0.38	2.10	15.82
1908	0.00	0.09	0.27	.....	0.37	2.08	0.80	0.18	0.45	1.31	0.30	0.40	.....
1909	3.50	0.98	1.07	0.10	0.34	1.43	0.43	0.00	0.89	0.65	3.28	0.70	13.37
1910	2.65	1.96	.....	.....	0.58	0.88	0.70	Tr.	.....	.....	.....	.....	.....
1911	.....	.....	.....	1.41	0.82	1.04	0.16	Tr.	1.51	0.72	.....	0.43	.....
1912	0.92	0.22	0.92	1.34	1.44	1.97	0.76	1.45	0.46	0.22	0.88	1.88	12.46
1913	1.37	0.39	0.10	0.90	0.96	1.69	1.84	1.10	0.07	0.08	1.40	1.32	11.22
1914	2.59	0.39	0.18	1.14	2.09	0.43	0.32	Tr.	0.54	1.17	0.25	0.18	9.28
1915	0.43	1.86	0.62	0.23	0.77	.....	1.36	.....	.....	.....	.....	.....	.....
Mean	1.18	1.06	1.01	0.83	1.20	1.06	0.62	0.37	0.63	0.81	0.99	1.07	10.83†

*Station established by the Signal Service, October, 1889.
†Sum of monthly means.

Digitized by Google

During the period, January 1910 to September 1915, for which complete records of rainfall at Silver Lake, Cliff and Fort Rock are available, the mean annual rainfall for these stations was 10.6 inches, 10 inches and 9.64 inches respectively. Silver Lake and Fort Rock being nearer the mountains, show a heavier precipitation during the fall, winter and spring months, while Cliff shows higher precipitation during May and June.

Probable Influence of climate on nature of crops.—An examination of the following tables on frost data indicates that a freezing temperature of 32° may be expected to occur once or twice even in the warm summer months, the station at Silver Lake showing an average for the eight-year period of 1.6 days, while Cliff shows an average 4.8 days. If we consider this temperature of 32° as a killing frost, it will be shown in the tabulation of frost data covering this period of years that about 40 days is all that can be considered safe for growing crops, and that in that time, three years of the eight have one frost each in the 40-day period.

It is well known that in this region good crops of the hardier varieties of grains and vegetables have been matured since this country was first settled. It thus seems that these records, obtained with regulation shelters about four or five feet above the ground, give temperatures several degrees colder than actually occur at the ground, or that the crops generally grown in this country are not injured by temperatures of 32° for a few hours. In confirmation of this statement the following is quoted from Edward A. Beals, District Forecaster, U. S. Weather Bureau, Portland, Oregon.*

"The assumption that a temperature of 32° registered for a few minutes at 4½ feet above the ground by thermometers exposed in a regulation shelter, is equivalent to a killing frost cannot be taken seriously in this locality, for these temperatures have occured on several occasions during the period of crop growth without doing any harm. It is well known that perishable products will stand temperatures several degrees below the freezing point without being injured when in transit, and Mr. H. E. Williams, Assistant Chief of the Weather Bureau, in Farmers' Bulletin No. 125, gives a list of these products and the temperatures they will bear without injury. According to this authority, cabbages, beets, turnips, cauliflower and onions can be subjected to temperatures of 26°, or a trifle lower, without being damaged. Apples lying loose can stand a temperature of 28° before they are harmed, and plant pathologists have stated that it takes a temperature of 25° to injure apples after the fruit has set, although when in bloom temperatures of 28° or 29° may be injurious.

"As a further illustration of the misleading nature of a temperature of 32° in a dry country, Mr. P. C. Day, Chief of the Climatological Division of the Weather Bureau, states in Bulletin V, published in 1912: 'On some of the high plateaus of the western country freezing temperatures are liable to occur in all months of the summer, but their effect on vegetation is not so pronounced as in the districts east of the mountains." Such are the conditions found in the Klamath Basin, and a temperature of 32°, or

*Climatic characteristics of the Oregon-California Government Irrigation Project, 1913.

Digitized by Google

even five or six degrees lower, seldom causes damage, except to tender vines, for the reason that the air is dry and the low temperatures last but a short time."

Beals also says that

"Owing to the dryness of the air, frost does not always form with temperatures as low as the freezing point or even four or five degrees below that mark, and the hardier varieties of vegetation are seldom seriously injured by low summer temperatures."

Accordingly the following tables have been prepared showing the first date, last date and number of days on which temperatures of 32° and 26° were reached, for each of the summer months of the years 1907 to 1915 inclusive.

Frost Data—April

Year.	Station.	Freezing 32° and below.			Freezing 26° and below.		
		First Date.	Last Date.	No. of Days.	First Date.	Last Date.	No. of Days.
1907	Silver Lake.....	1	26	16	1	26	10
1908	*Christmas Lake....	1	30	23	1	29	17
1909	Silver Lake.....	1	30	28	3	30	25
	Christmas Lake....	1	30	29	1	30	24
1910	Silver Lake.....	.....	.....	.....	.....	.....	.....
	Christmas Lake....	3	29	18	3	29	12
1911	Silver Lake.....	2	30	22	6	30	15
	Cliff.....	1	30	27	1	30	21
1912	Silver Lake.....	1	30	27	1	27	15
	Cliff.....	1	30	27	1	27	20
1913	Silver Lake.....	1	30	26	7	30	15
	Cliff.....	1	30	28	2	30	19
1914	Silver Lake.....	1	30	22	1	30	14
	Cliff.....	1	30	24	6	30	10
1915	Silver Lake.....	9	30	19	13	30	11
	Cliff.....	3	30	26	4	30	18
Mean	Silver Lake.....	.....	.....	23	.....	.....	15
	Cliff.....	.....	.....	25	.....	.....	18

*Christmas Lake was the name applied to observations taken at Cliff postoffice until May, 1911, when it was changed to Cliff.

Digitized by Google

Frost Data—May

Year.	Station.	Freezing 32° and below.			Freezing 26° and below.		
		First Date.	Last Date.	No. of Days.	First Date.	Last Date.	No. of Days.
1907	Silver Lake.....	1	25	14	1	23	6
1908	Silver Lake.....	1	31	25	1	28	14
	Christmas Lake....	1	31	27	3	30	17
1909	Silver Lake.....	1	29	21	1	23	18
	Christmas Lake....	1	29	27	1	29	20
1910	Silver Lake.....	11	28	12	15	28	2
	Christmas Lake....	1	30	20	1	21	9
1911	Silver Lake.....	6	30	18	6	28	9
	Cliff.....	1	31	22	6	30	17
1912	Silver Lake.....	1	31	20	2	30	3
	Cliff.....	1	31	21	2	30	9
1913	Silver Lake.....	1	21	16	1	19	6
	Cliff.....	1	29	19	1	19	10
1914	Silver Lake.....	1	28	6	.....	.....	0
	Cliff.....	1	29	15	1	28	8
1915	Silver Lake.....	1	31	26	2	25	9
	Cliff.....	1	31	18	1	29	12
Mean	Silver Lake.....	.....	.....	17.5	.....	21	7.3
	Cliff.....	.....	.....	21.0	.....	27	12.8

Digitized by Google

Frost Data—June

Year.	Station.	Freezing 32° and below.			Freezing 26° and below.		
		First Date.	Last Date.	No. of Days.	First Date.	Last Date.	No. of Days.
1907	Silver Lake	1	24	10	24	24	1
1908	Silver Lake	8	29	10	.....	.....	0
	Christmas Lake	1	28	18	1	28	8
1909	Silver Lake	6	13	5	.....	.....	0
	Christmas Lake	5	30	16	5	28	6
1910	Silver Lake	.....	.....	.....	.....	.....	.....
	Christmas Lake	2	28	16	2	21	8
1911	Silver Lake	4	29	6	4	4	1
	Cliff	2	25	9	2	5	3
1912	Silver Lake	15	30	4	.....	.....	0
	Cliff	3	21	7	15	21	3
1913	Silver Lake	5	10	2	.....	.....	0
	Cliff	5	28	7	20	20	1
1914	Silver Lake	5	26	10	5	7	3
	Cliff	4	26	10	5	22	4
1915	Silver Lake	.....	.....	.....	.....	.....	.....
	Cliff	3	29	22	8	26	7
Mean	Silver Lake	.....	.....	6.7	.....	.....	0.7
	Cliff	.....	.....	13.1	.....	.....	5.0

Digitized by Google

Frost Data--July

Year.	Station.	Freezing 32° and below.			Freezing 26° and below.		
		First Date.	Last Date.	No. of Days.	First Date.	Last Date.	No. of Days.
1907	Silver Lake	.....	.....	0	.....	.....	0
1908	Silver Lake	17	17	1	.....	.....	0
	Christmas Lake	6	29	5	.....	.....	0
1909	Silver Lake	7	18	2	18	18	1
	Christmas Lake	7	28	6	7	18	2
1910	Silver Lake	.....	.....	.....	.....	.....	.....
	Christmas Lake	5	5	1	.....	.....	0
1911	Silver Lake	1	8	2	.....	.....	0
	Cliff	1	31	8	8	8	1
1912	Silver Lake	1	3	2	.....	.....	0
	Cliff	1	23	7	.....	.....	0
1913	Silver Lake	13	17	3	.....	.....	0
	Cliff	2	30	5	.....	.....	0
1914	Silver Lake	21	21	1	.....	.....	0
	Cliff	21	22	2	21	21	1
1915	Silver Lake	15	18	3	.....	.....	0
	Cliff	7	26	10	14	17	2
Mean	Silver Lake	.....	.....	1.8	.....	.....	0.14
	Cliff	.....	.....	5.5	.....	.....	0.75

Digitized by Google

Frost Data—August

Year.	Station.	Freezing 32° and below.			Freezing 26° and below.		
		First Date.	Last Date.	No. of Days.	First Date.	Last Date.	No. of Days.
1907	Silver Lake	15	31	12	27	28	2
	Christmas Lake	19	31	10	19	31	4
1908	Silver Lake	3	30	12	24	26	3
	Christmas Lake	2	31	14	11	31	8
1909	Silver Lake	6	26	3	26	26	1
	Christmas Lake	2	30	18	2	29	6
1910	Silver Lake	12	31	9	29	30	2
	Christmas Lake	2	31	22	15	30	7
1911	Silver Lake	5	21	3	.....	.....	0
	Cliff	2	29	14	20	20	1
1912	Silver Lake	29	31	2	.....	.....	0
	Cliff	4	30	10	30	30	1
1913	Silver Lake	18	19	2	.....	.....	0
	Cliff	15	31	5	18	19	2
1914	Silver Lake	18	31	5	.....	.....	0
	Cliff	8	31	9	17	31	2
1915	Silver Lake	.....	.....	.....	.....	.....	.....
	Cliff	0	0	0	0	0	0
Mean	Silver Lake	.....	.....	6.0	.....	.....	1.0
	Cliff	.....	.....	11.4	.....	.....	3.44

Digitized by Google

Frost Data—September

Year.	Station.	Freezing 32° and below.			Freezing 26° and below.		
		First Date.	Last Date.	No. of Days.	First Date.	Last Date.	No. of Days.
1907	Silver Lake.....	2	30	21	12	30	10
	Christmas Lake....	1	30	22	2	30	14
1908	Silver Lake.....	2	30	18	7	29	11
	Christmas Lake....	1	30	18	1	30	12
1909	Silver Lake.....	8	30	9	18	25	3
	Christmas Lake....	8	30	14	11	30	9
1910	Silver Lake.....	.....	.....	.....	.....	.....	.....
	Christmas Lake....	1	30	22	1	29	14
1911	Silver Lake.....	6	29	17	18	28	4
	Cliff.....	2	30	19	11	29	13
1912	Silver Lake.....	3	29	14	14	23	4
	Cliff.....	1	30	25	1	29	15
1913	Silver Lake.....	1	30	9	9	26	5
	Cliff.....	1	30	21	1	30	13
1914	Silver Lake.....	1	30	20	9	30	5
	Cliff.....	1	30	19	5	30	14
1915	Silver Lake.....	.....	.....	.....	.....	.....	.....
	Cliff.....	1	30	29	2	30	19
Mean	Silver Lake.....	.....	.....	15.4	.....	.....	6.0
	Cliff.....	.....	.....	21.0	.....	.....	13.7

If 26° be considered the critical temperature for the crops grown, the period of forty days referred to can be lengthened to ninety-four days with only a one day exception in the eight years.

The following table has been compiled especially to show the period of time between the last dates in the spring and the first dates in the fall when temperatures of 32° and 26° may occur.

Last dates in spring and first dates in fall of temperatures of 32° and 26° Fahrenheit at Silver Lake, Oregon, one day exceptions noted as below.

Year.	32° and below.			26° and below.		
	Last date.	First date.	No. days	Last date.	First date.	No. days
1907.....	June 24....	Aug. 15....	51	June 24....	Aug. 27....	63
1908.....	a June 29....	Aug. 3....	34	May 28....	Aug. 24....	77
1909.....	July 18....	Aug. 6....	18	b May 23....	Aug. 26....	94
1910.....	c May 28....	Aug. 12....	75	May 28....	Aug. 29....	92
1911.....	July 8.....	Aug. 5....	27	June 4.....	Sept. 18...	105
1912.....	July 3.....	Aug. 29....	56	May 30....	Sept. 14...	106
1913.....	July 17....	Aug. 18....	31	May 19....	Sept. 9...	112
1914.....	d June 26....	Aug. 18....	52	June 7.....	Sept. 9...	93
Mean.....	June 30....	Aug. 13....	43	June 1.....	Sept. 4.....	94

a July 17 only, 32°.
b July 18 only, 26°.
c June and July temperatures not recorded.
d July 21 only, 32°.

Digitized by Google

It will be noted that while the average length of period free from temperatures of 26° and below is 94 days, the average period for the last four years is 104 days. It has been estimated that in Europe it takes a period of 127 days without frost to mature wheat. If this condition obtained in the Silver Lake country wheat could not be considered a safe crop. Nevertheless during the period covered by the records given above, now under consideration, crops of wheat have been matured. The abundance of sunshine and the relatively warm temperatures during the day no doubt tend to mature grains more rapidly than in the eastern part of the United States or in Europe. The growing season for barley, oats and rye is from ten days to three weeks less than that for wheat, and consequently these grains might be considered safe crops to undertake.

Very little alfalfa or clover has been grown in the vicinity of Silver Lake, so little is known of the yield or the number of crops which may be cut. It is believed that two crops may be cut but that in occasional years a stand of alfalfa might be injured by early frosts, thus making it a difficult, though not impossible crop to raise successfully. Good crops of timothy have been raised, and it is thought that clover can be successfully grown.

GEOLOGY

The earliest account of the geology of northern Lake County may be found in the Fourth Annual Report of the U. S. Geological Survey, 1882-83. In 1882 I. C. Russell came through from the Harney Basin by way of Sand Springs and Christmas Lake to Silver Lake. Speaking of the isolated peaks, including the Glass Buttes and other prominent peaks to the north and east of Christmas Lake Valley, Russell says:

"Through the region in which these isolated peaks are found, the basin range structure is obscure or wanting, the topographic forms indicating other and probably older conditions.

The prominent features are due mainly to erosion and to the extravasation of volcanic material and not to the tilting of orthographic blocks."

From Silver Lake, Russell went south along Summer Lake. Speaking of the character of the lake region with regard to its geological interest he says:

"The ruggedness of its topography and the abruptness of the precipices enclosing the valleys are mainly due to orthographic displacement. The numerous fault-scarps form precipitous palisades across the country, from a few hundred to fifteen hundred or two thousand feet in height trending approximately north and south but sometimes unbroken by passes for a distance of 50 miles. The depressed blocks give rise to rock basins some of which are occupied by lakes that mirror on their placid bosoms the rugged grandeur of the surrounding walls. A few of the lakes are remnants left after long concentration by evaporation; while others of even greater interest are fresh or nearly fresh but occupy ancient basins from which the waters have never overflowed. * * * * *

This lake region is not only remarkable for the ruggedness of its scenery, but furnishes a unique example of displacement on a grand scale, and at such a recent date that the fault-scarps still form beetling cliffs that appear to have been up-raised but yesterday."

Digitized by Google

SILVER LAKE FROM ROAD NEAR SUMMIT TO SUMMER LAKE LOOKING NORTHWEST PLATE 3

PAULINA MARSH FROM THE NORTH END PLATE 4

Digitized by Google

Digitized by Google

The above description by Russell of lakes in this vicinity is especially appropriate to Silver Lake, where apparently the displacement is in the form of a depression in an anticline leaving two prominent fault-scarps transverse to its axis, one on the east and the other on the west side of the lake, rising to an elevation of 400 to 800 feet above its surface.

In describing the Quatenary Lakes of southern Oregon, Russell further says:

"The Quatenary lake that flooded the valley of Silver and Christmas Lakes had a depth of something more than 100 feet over a large area and formed an extensive water surface.

On following the ancient water lines we found them continuous throughout, thus proving that the lake which formed them was without a channel of overflow."

Signs of this water line spoken of by Russell may be found in numerous places around the borders of the Fort Rock Basin, the most convincing being the evidence of wave action well up on Fort Rock. Other indications of the presence of high water are found in the hills to the north of Silver Lake as well as around the lake itself.

At the time Russell visited Silver Lake in 1882 it had never been known to dry up. He found the water fresh and explained it on the theory of dessication, that is at different periods in the past the lake had probably gone dry and the saline matter deposited was afterwards covered by sediment from the inflow during the periods of high water which followed. The lake went dry in the year 1889, since Russell's trip. At the present time it is also at very low stage, soundings taken in July, 1915, showing a depth of but three and a half feet.

Some crops have been planted along the exposed borders of the lake this season. This has not been done before since 1889, when the settlers in that region farmed its bed. Settlers who planted crops in the year 1889 report evidence of sage-brush growth in the bed of Silver Lake, which would indicate that at some time before this region was settled, the lake had been dry for at least a few years.

A more detailed description of the geologic features of this region is given by Gerald A. Waring,* who made a reconnaissance of Lake County in 1907. The following is quoted from Waring, omitting portions of his description which do not relate to the Silver Lake basin, Fort Rock and Christmas Lake Valleys:

"*Character and age of rocks:* —In studying the geology of the region—the kinds of rocks and their structure—all of the consolidated materials that were seen are volcanic effusives and related volcanic muds, or tuffs. These rocks belong to several lithologic classes and to more than one geologic period, but by far the most extensive series is that of the basaltic flows. These cover nearly all of Lake County and extend eastward beyond Stiens

*Gerald A. Waring, Geology and Water Resources of a portion of South Central Oregon, Water Supply Paper 220, 1908.

Digitized by Google

Mountain and northward beyond the John Day region, where fossils that have been collected from interbedded sedimentaries determine the age of the flows as Miocene.

No such fossil-bearing beds were found in the Lake County area, and the effusive material was not traced in detail to the place where such beds are exposed. But the material is so similar in lithologic character, in the amount of deformation it has undergone, and in its general relation to the Cascade Range to the west that there is little hesitation in placing it in the same general series with the widely extended and well-known Miocene lavas of Washington and northern central Oregon. Although these Miocene basaltic lavas cover nearly all of the region examined with the exception of the lake valley there are sufficiently large areas of lavas of other types to warrant a preliminary separation into three groups—older acidic effusives, older basaltic effusives, and recent eruptive material. * * *

Classes of Rocks. —The rocks of several mountain masses in this region differ enough from the more common basalts, both in the nature of the topography to which they give rise and in their petrologic character, to warrant us in considering them as belonging to an earlier period of more acidic effusion, when the lavas poured out were andesites, rhyolites, and related obsidians. They are perhaps of early Tertiary or pre-tertiary age. In the succeeding effusions the materials were either basaltic or tuffaceous. * * *

Gray Butte, Big Juniper Mountain and Horning Bend are composed of light-colored rocks that appear also to have been disturbed and eroded before the outpouring of the later basalts. They are rhyolitic in character. * * *

Basalts. —The basalt of the main flows over the surface of the country is for the most part a dark gray, fine-grained, rather vesicular rock, weathering on the more level areas into brown rounded cobbles and boulders that make a very uneven surface, difficult to travel over.

On the higher peaks the more resistant types of this rock contain much iron and strongly affect the compass needle. Very little soil has formed over these high desert areas. Approximately parallel partings, usually at intervals of only a few feet, mark the division between successive flows, but in some places much thicker beds are exposed. Fissures nearly perpendicular to the parting planes break the basalt into blocks, which by transverse fracturing are reduced to smaller and smaller fragments, forming the characteristic talus slopes of the cliffs.

Tuffs. —In several places over the northern and western parts of the county there are remnants of a great tuffaceous flow or series of flows. This tuff underlies the upper flows of the basalt, but probably belongs to the same general period of effusion. Fort Rock, an isolated mass in the northwestern part of Christmas Lake Valley, is the most prominent of these remnants. It is imperfectly crescent shaped, nearly one-third of a mile across, and rises in its highest part 325 feet above the valley floor, with perpendicular cliffs 200 feet above its talus slopes. The tuff of which it is composed is a tawny, rather firmly cemented material, consisting of fragments of effusive rocks and volcanic cinder. This material is largely used in the western part of the county for building purposes, being soft when first quarried and easily cut into blocks that harden on exposure, and as it is used especially for chimneys it is locally known as "chimney rock." * * *

Interbedded with the basalts are thinner layers of tuff, or volcanic mud and ash. These are usually rather fine grained, white or red in color, and contain fragments of basaltic rocks. Where exposed along cliffs these tuff beds thin out, as if lenticular in shape, and in some instances serve to accentuate any unevenness in the associated basalt beds.

Recent Eruptive Material. —In the northern part of the county is an area covered by sheets of lava and small volcanic cones or craters that represent a very recent period of volcanic eruption. Black vesicular basaltic rock constitutes the main part of the flow, while the cones are built up of slaglike fragments of scoria and volcanic bombs. This material clearly was ejected at a period much later than that of the great Miocene flows. It is probably Pleistocene in age.

Digitized by Google

The loose Pleistocene filling of the valleys and the alluvial material brought down by streams may be considered as a fourth class of surface material in this region.

Lake Deposits. —No marine beds were seen, but some lake deposits should be mentioned here. Along the hills east of Summer Lake, and fully 150 feet above its present level, there are beds aggregating 25 feet or more in thickness. These are composed of basaltic pebbles and shells of freshwater mollusks, cemented into a conglomerate by lime carbonate. * *

In all of the lake valleys there are deposits of silts, sands, and clays that form the floor of the valley and usually bury any coarser material that may be in the basin. Remains of Pleistocene mammals fix the age of these deposits at Fossil Lake, in Christmas Lake Valley, where somewhat extensive collections have been made by representatives of the Smithsonian Institution, and in 1904 by a party from the University of California.

Alluvium. —Some alluvium is to be found where the several streams debouch into the open valleys, but in few places is the area thus covered of great extent. * * *

Landslides and the slower weathering action that produces talus have also brought down much loose material from all the cliffs and steep slopes, but the areas covered by such material are not large.

Although in comparison with the great rocky basaltic areas these loose materials are geologically of minor importance, it is from them that practically all of the limited quantity of ground water now used is obtained. Hence from the view point of the present water resources in the region this fourth class of unconsolidated material is perhaps the most important. The cultivable land is also limited to these areas of lake and stream deposits." * * *

WATER RESOURCES

Paulina Marsh Drainage.—Three streams enter Paulina Marsh from the timbered mountain slopes to the south and west. The relative positions and areas of their drainage basins are shown on Sheet No. 37.

Silver Creek, the largest of these streams, rises from a spring in Thompson Valley. Two of its branches enter this valley from the east and two from the west. Benney and Squaw Creeks rise on the western slope of Winter Ridge and in their lower courses drain the south slope of Hager Mountain and the north slope of Sycan Butte. The two branches from the west drain the north slope of the eastern extension of Yamsay Mountain. This area, drained through Thompson Valley, is practically all timbered and above 5,000 feet elevation, and furnishes a large percentage of the run-off of Silver Creek. The West Fork of Silver Creek rises in the northeast slope of Yamsay Mountain and joins the main stream about three miles above the town of Silver Lake. The total area drained is 180 square miles. The Bridge Creek drainage area lies next to the west of the Silver Creek drainage, and is generally lower and less wooded. The total area drained is 53 square miles.

Buck Creek heads on the north slope of Yamsay Mountain, which rises to an elevation of 8,300 feet above sea level. In its lower course, with the exception of the Emory reservoir site, the

Digitized by Google

creek follows a canyon about 100 feet deep until it reaches the western slope of Paulina Marsh about three miles northwest of Silver Lake. The total area drained is uncertain.

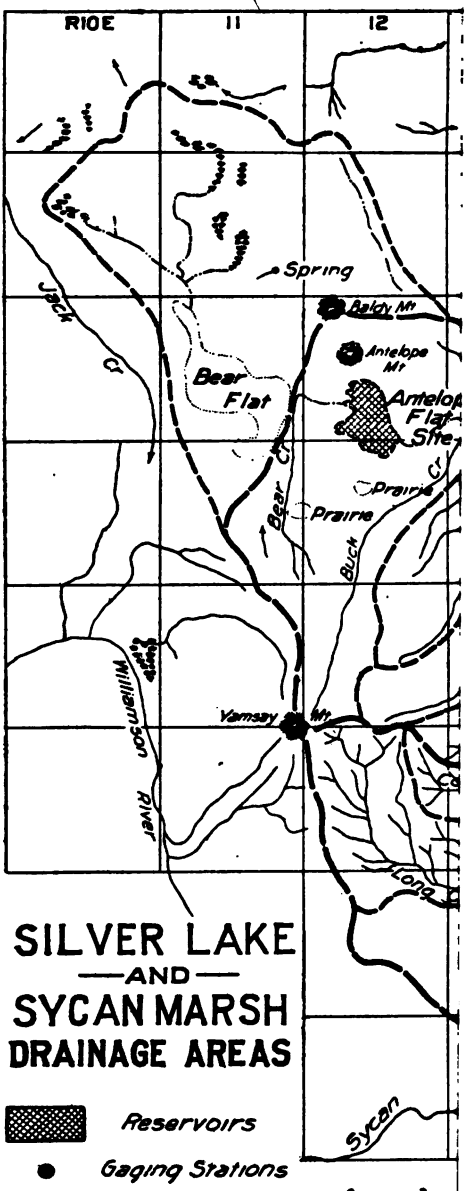
There was considerable uncertainty as to the name that should be applied to this stream, up to the time of the present investigation. Old maps and records of the U. S .Geological Survey give it the name of "Buck Creek" or "Bear Creek" or "Buck (or Bear) Creek." From local information and a trip made by Paul V. Hodges in the summer of this year from Silver Lake westward through Antelope Flat and Bear Flat, it has been ascertained that Bear Creek is a small stream rising on the north slope of Yamsay Mountain, flowing northward to an outlet from Bear Flat into Antelope Flat, and that this stream discharges into Antelope Flat during high run-off stages, the water eventually finding its way through Antelope Flat to Buck Creek. The main stream, however, and the one furnishing nearly all of the run-off to Paulina Marsh, is Buck Creek. Accordingly this is taken as the proper name for the stream below the junction of the two.

The drainage area has heretofore been given as 77 square miles, but did not include the area drained by Bear Creek. See Sheet No. 37. It now seems certain that the area drained by Buck Creek, including the area drained through Antelope Flat, but exclusive of Bear Flat drainage, is about 110 square miles. Northwest of Bear Flat is a heavily timbered area of probably 140 square miles, the drainage from which collects in numerous small swamps. In years of high run-off this drainage may find its way to Bear Flat and it would appear, from the fact that there is an old outlet between Bear and Antelope Flats, that at times water may have drained into Antelope Flat and consequently into Buck Creek from this large area. The possibility of developing a water supply from this area by drainage channels may be worthy of investigation when conditions make water more valuable for irrigation.

These three streams entering Paulina Marsh furnish a mean annual discharge of approximately 60,000 acre feet. Most of this run-off comes during the spring months and is due to the melting of winter snows.

Precipitation in the shape of rainfall during the remainder of the year is very light. Silver Creek and Buck Creek are very similar in the character of their run-off, which in both streams reaches a maximum at about the same time. This stage may be reached at any time from early April to late May. The Silver Creek discharge ranges in a mean year from 250 second feet during the month of high run-off to about 15 second feet in July. This discharge is usually maintained throughout the summer months, due probably to the fact that near its source are numer-

Digitized by Google



SILVER LAKE
—AND—
SYCAN MARSH
DRAINAGE AREAS

Reservoirs

Gaging Stations

OREGON COOPERATIVE WORK	
U. S. Reclamation Service and State of Oregon	
Project	SILVER LAKE
Feature	Silver Lake & Sycan Marsh Drainage Areas
Designed or	Reservoir Sites & Gaging Stations Date
Surveyed by	
Drawn by	Parkhill 7-15
Traced by	Rullman "
Checked by	Parkhill
Scale	0 1 Miles Project File No. 37

Digitized by Google

Digitized by Google

ous springs, one of which rises near Small's cabin in Thompson Valley. This spring had an estimated discharge of 10 second feet in October, 1914.

The discharge of Buck Creek ranges from about 60 second feet during the high spring month to about 5 second feet in July, this rate continuing throughout the summer months.

The highest monthly discharge of Bridge Creek usually comes a month later than that of Silver and Buck Creeks, and is about 20 second feet in a mean year. In all years but those of excessive run-off Bridge Creek nearly disappears in the late summer months.

Following is a tabulation of the annual discharges of Silver, Buck and Bridge Creeks, with the missing years estimated from partial records, from comparisons with Chewaucan River run-off for corresponding years and from a probability curve computed from ten streams in Eastern Oregon. Some of these years estimated may be considerably in error, but it is believed that the estimated annual discharge for the period considered is not far wrong, since Silver Creek furnishes at least two-thirds of the run-off. Only two years of the twelve year period on Silver Creek are entirely estimated. In the four years partly estimated the actual measurements covered the months of greatest discharge, leaving only the months of small discharge to be estimated. Four years of the Buck Creek discharge may be considered fairly reliable, and three years of the Bridge Creek records.

The run-off per square mile estimated for Bridge Creek for the twelve year period is less than half that for the Silver Creek discharge. This may be due to the generally lower altitude and less heavily timbered slopes drained by Bridge Creek, or comparatively more of the run-off may be lost through underdrainage. Also the area drained is entirely a north slope of Yamsay Mountain, and the consequent delayed melting of snows may give rise to a greater loss by evaporation.

Digitized by Google

Annual Run-off to Paulina Marsh—years 1903-1904 to 1914-1915

Year.	Silver Creek.	Buck Creek.	Bridge Creek.	Total.
	Acre feet.	Acre feet.	Acre feet.	Acre feet.
1903–04	*72,800	*27,600	*9,600	110,000
1904–05	25,460	10,000	1,900	37,360
1905–06	40,550	13,330	5,000	58,880
1906–07	a66,600	b26,000	c8,800	101,400
1907–08	*26,800	*10,400	*3,550	40,750
1908–09	39,300	17,100	c5,200	61,600
1909–10	53,130	21,320	c7,000	81,450
1910–11	44,840	b17,400	d3,780	66,020
1911–12	32,000	b12,500	c4,200	48,700
1912–13	31,800	b12,400	c4,200	48,400
1913–14	37,700	b14,700	c5,000	57,400
1914–15	13,560	b 5,300	c1,600	20,460
Total	484,540	188,050	59,830	732,420
Estimated Mean	40,380	15,660	4,990	61,035

a Estimated from partial records.
b Estimated from ratio 39 per cent of Silver Creek.
c Estimated from ratio 13 per cent of Silver Creek.
d Estimated from rating curve and 1 to 4 measurements per month.
* Obtained from probability curve computed from discharge of 10 streams in eastern Oregon.

Sycan Marsh Drainage.—Sycan Marsh is located about twenty miles south of the town of Silver Lake, and with its tributaries, is the source of the lower Sycan River, a branch of Sprague River. Sycan Marsh is 5,100 feet above sea level, its elevation being about the same as that of Thompson Valley, from which it is separated by a low divide about 40 feet above the surface of the marsh.

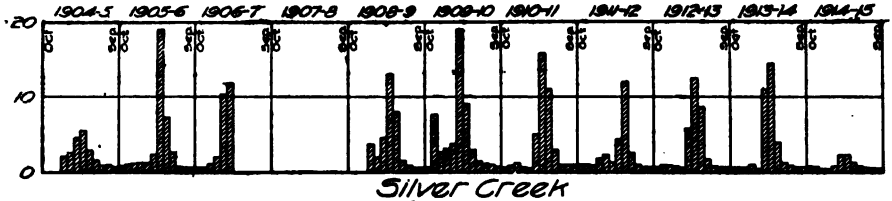
The Sycan Marsh drainage area covers about 300 square miles, reaching from Winter Ridge on the east to Yamsay Mountain on the west. Two tributaries enter the marsh on the eastern side, the principal one being the upper Sycan River which drains a territory of 124 square miles. The area drained is heavily wooded and its elevation ranges from 5,100 feet at the marsh to 7,000 feet at the river's source. See sheet No. 37.

Chocktoot Creek enters the marsh about a mile north of Sycan River. The territory drained is approximately 38 square miles and is similar in character to that of Sycan River.

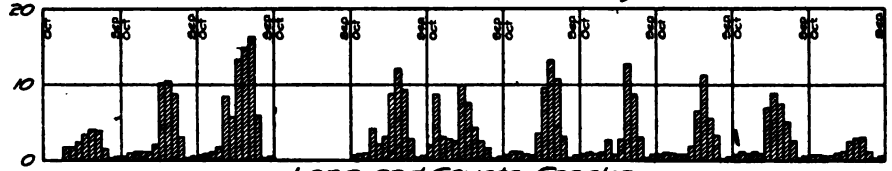
Long and Coyote Creeks enter the marsh from the west and drain a territory approximately 56 square miles in area. Long Creek, the larger of the two, drains the heavily timbered slopes on the northeast side of Yamsay Mountain. Coyote Creek north of Long Creek drains the south slope of a ridge forming the eastern extension of Yamsay Mountain.

From local information it seems that there is very little discharge from Sycan Marsh in ordinary years except during the very short time when that of tributary streams is at a maximum. This is borne out by a study of the discharges of the lower Sycan River at Yainax.

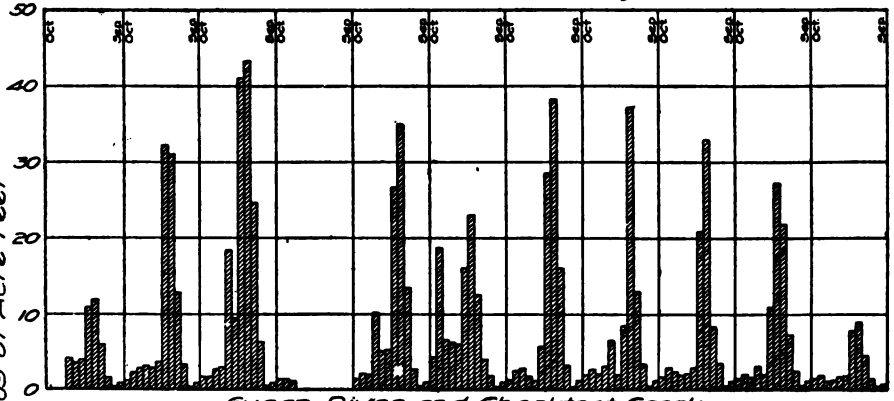
Digitized by Google



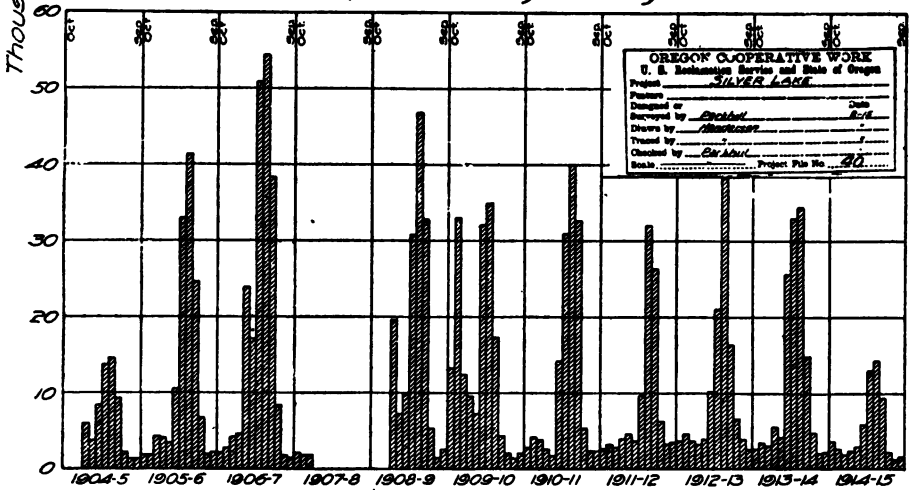
Silver Creek
Recorded Monthly Discharge



Long and Coyote Creeks
Estimated Monthly Discharge



Sycan River and Chocktoot Creek
Estimated Monthly Discharge



Chewaucan River
Recorded Monthly Discharge

Digitized by Google

Digitized by Google

The position and area of Sycan Marsh drainage, relative to that of Silver Creek, may be seen on Sheet No. 37. The only records available were obtained in the summer of 1905 and are shown under "Gaging Stations and Records of Flow".

A study of comparative discharges of Sycan River above the marsh with those of the Chewaucan River and Silver Creek has been made, as tabulated below. From these the probable mean yearly discharge of Sycan Marsh tributaries has been estimated for the period 1905 to 1915. See also estimated discharges of these streams shown on hydrograph, Sheet No. 40.

Comparison of Discharge of Sycan River above marsh with those of Chewaucan River and Silver Creek

March to October, 1905.	Acre feet discharge.	Ratio to Sycan.
Sycan River above Marsh	27,600	1.00
Chewaucan River	52,200	1.90
Silver Creek	18,400	.665

Comparison of Discharge of Long Creek and Coyote Creek with that of Sycan River above Sycan Marsh

March to July, 1905.	Acre feet discharge.	Ratio to Sycan.
Long Creek	13,600	.53
Coyote Creek	1,250	.05
Sycan River	26,000	1.00

Long and Coyote Creeks discharge approximately 58 per cent as much as Sycan River above Sycan Marsh.

Probable Mean Yearly Discharge into Sycan Marsh from Tributaries, 1905-1915

Tributary.	Ratio to Sycan.	Discharge in acre feet.	Drainage area square miles.	Run-off in inches.
Sycan River	1.00	64,800	124	9.8
Chocktoot Creek	*.30	19,400	38	9.8
Long Creek and Coyote Creek	.58	37,500	56	12.5
Total		121,700	218	10.9

*Based on comparative drainage area and one comparative measurement in 1905. See Miscellaneous Measurements of Streams entering Sycan Marsh under Gaging Stations and Records of Stream Flow.

Silver Lake Drainage.—Silver Lake receives the yearly overflow of Paulina Marsh into which Silver Creek, Bridge Creek and Buck Creek flow. One small stream, Duncan Creek, flows directly into Silver Lake on the west side, at the farm owned by F. D. Duncan, from which the creek receives its name. No records are available of the discharge of Duncan Creek or of the inflow from Paulina Marsh. A gage for recording the height of the water surface in the lake was established early in 1905 by the U. S. Geological Survey. Very few records are available and these are insufficient to make any study in detail of the

Digitized by Google

inflow to the lake by years. No records were kept after June, 1905, until the present investigation. On September 17, 1904, the water surface was noted to be 1.5 feet below high water marks on boulders. A topographic survey made at the inlet to Silver Lake and at the gap between Silver and Thorn Lakes in January, 1905, shows the water surface at elevation 4,440.6 feet, and that Silver Lake and Thorn Lake were united by a channel varying from 50 feet to 200 feet in width. The comparatively high run-off of the spring of 1904 filled Silver Lake and caused it to overflow into Thorn Lake. Since that time Silver Lake has gradually gone down until it is now 6.5 feet below the elevation at which it overflows into Thorn Lake. Two conclusions may be reached; either that the run-off of the streams tributary to Paulina Marsh has been below normal since 1905 or that the increased use of the waters of those streams has resulted in a diminished overflow from the marsh into Silver Lake and a consequent gain of evaporation from its surface over inflow. The lake surface has fallen 1.4 feet from November 2, 1914, to July 22, 1915. This gives an estimated evaporation rate of about 3.0 feet per year. See "Seepage and Evaporation", and precipitation records.

During the ten year period from January, 1905, to January, 1915, the lake surface of 10,000 acres would lose, on this basis, about 300,000 acre feet in evaporation. The amount of water in the lake is less by 65,000 acre feet. Following is a tabulation of the estimated losses from and inflow to Silver Lake in a ten year period.

Estimated Losses from and Inflow to Silver Lake, 1905-1915.

Evaporation—10,000 acres, 10 years 3 feet depth	300,000	acre ft.
Decrease in contents of lake, 10,000 acres, 6.5 feet depth	65,000	" "
Net supply by inflow and precipitation	235,000	" "
Precipitation, 10,000 acres, 10 years, 10 inch depth	83,300	a. f.
Inflow from Paulina Marsh and Duncan Creek	151,700	" "
	235,000	" "

Estimated mean yearly inflow 15,170 acre feet.

The above estimate covers the period 1905 to 1915, which misses the abnormally high run-off of 1903-04 but includes the low run-off of the last three years. Considering a period extending over a greater length of time, during which Silver Lake may be considered to hold its normal level, the inflow from

Digitized by Google

Paulina Marsh and Duncan Creek would have to supply about 2.2 feet in depth over the water surface of the lake to provide for evaporation in excess of precipitation on an area of 10,000 acres, or about 22,000 acre feet annually. The estimated mean annual discharge into Paulina Marsh is about 61,000 acre feet, so that about one-third of the discharge into Paulina Marsh must find its way into Silver Lake, the ratio being greater, as would be expected, in years of high run-off, and less in low years.

The water of Silver Lake is fresh, as demonstrated by analysis of a sample, made in 1914. The following is quoted from Walton Van Winkle*, who made the test:

"Silver Lake is about 15 square miles in extent at normal stage but is subject to marked fluctuations. It has dried up several times and it has overflowed, flooding Thorn Lake and the nearby desert. The frequent desiccations to which it has been subject have had a pronounced effect on the composition of its water. It is not strongly concentrated, as is common with the water of lakes in the Great Basin, but is fresh. The most satisfactory explanation of this phenomenon is that when the lake dries up its deposited mineral salts are blown over the desert and so dissipated, or are covered with an impermeable coating of silt and sand. When the lake is renewed there are no surface salts to be redissolved and consequently the water is fresh. The amount of freshening the water of Silver Lake undergoes by dilution and flooding into Thorn Lake is probably insignificant compared with that effected by frequent desiccations. Some of the irrigated lands bordering Silver Lake produce good crops."

In confirmation of the freshness of the water of Silver Lake it may be stated that the lake is stocked with trout which run up the creeks entering Paulina Marsh. In March of 1915 Mr. Parkhill and others observed a fish resembling the white fish, living in the small pond which is all that is now left of Thorn Lake. This lake must have been concentrated to less than one-hundredth the volume it had when united with Silver Lake. Fish could hardly live in this concentrated water of Thorn Lake if the water which came from Silver Lake were alkaline to a sufficient degree to be harmful to irrigation.

Following are the available records of Silver Lake gage heights:

*Water Supply Paper 363—Quality of the Surface Waters of Oregon—1914.

Digitized by Google

Gage Heights of Silver Lake, Oregon.

Date.	Gage Heights.	Elevation above Sea Level.
1904		
Sept. 17	*15.04	4,440.50
1905		
Jan. 17	15.22	4,440.76
Feb. 24	15.45	4,440.99
Feb. 27	15.50	4,441.04
Mar. 20	15.50	4,441.04
April 6	15.50	4,441.04
May 9	15.40	4,440.94
May 13	15.40	4,440.94
June 2	15.20	4,440.74
June 8	15.20	4,440.74
1914		
Nov. 2	9.96	4,435.50
1915		
July 19	8.58	4,434.12
July 22	8.55	4,434.09

*Estimated from high water mark.

Wells and Domestic Supply.—Throughout the Silver Lake, Fort Rock and Christmas Lake valleys there has been little difficulty in securing water for domestic purposes from wells, varying in depth from five to ten feet in the lower parts of the valleys to thirty or forty feet on the higher slopes. Generally speaking the quality of the water is good, especially in Silver Lake Valley and the west end of Fort Rock Valley, where the water is only slightly alkaline to the taste. There are exceptions, where the well is not favorably located. In the eastern end of Fort Rock Valley near Seven Mile Ridge the water from wells is distinctly alkaline to the taste, while in Christmas Lake Valley some of the wells have been abandoned as unfit for use on account of their strong mineral character. However, wells of usable quality have been found sufficient in number to supply the present needs of this valley without hauling water for domestic purposes more than a few miles.

Following is a tabulation of location, depth and material passed through, of a number of wells and auger holes throughout the valleys under discussion:

Digitized by Google

Wells and test holes in Fort Rock, Christmas and Silver Lake Valleys

No. of Well.	Owner.	Location.			Depth in feet.	To water in feet	Material passed through.
		T.S.	R.E.	Sec.			
1	Mr. Beard.....	25	18	6	22	20	Lake silts.
2	(Test well).....	25	17	1	30	(?)29	Lake silts (water not used).
3	Mr. Gaskell.....	25	18	6	28	25	Lake silts.
4	J. W. Hanley....	25	18	.....	35	25	Do.
5	Mr. Beard, Sr....	25	18	.....	25	Dry	0-18, silts; 18-25, rotten basalt.
6	Mr. Whitney.....	25	19	.....	12	11	Lake silts; a little rotten basalt at bottom.
7	Dr. Ewing.....	25	19	.....	10	9	0-6, silts; 6-10 rotten basalt.
8	Dr. Thayer.....	25	19	.....	12½	10	Lake silts.
9	Joe Kasperonez..	25	18	25	12½	11	Lake silts; a little rotten basalt at bottom.
10	Frank Polte.....	25	18	25	4	Dry	0-1½, silts; 1½-4, rotten basalt.
11	Mr. Wardall.....	25	19	28	13½	12	Lake silts.
12	James Wilson....	25	19	29	12	8	Do.
13	James McCurdy.. (3 wells.)	25	19	32	16 14 12	10 10 10	0-4, silts; remaining depth sand with streaks of clay.
14	John C. Green...	25	19	31	12	10	Lake silts.
15	W. A. McHargue.	25	19	31	13	11	Do.
16	Mr. McCurdy....	26	19	.....	17	15	Do.
17	Mr. Brown.....	26	19	.....	11½	9	Lake silts; a little basalt at bottom.
18	Mr. Lanning.....	26	18	.....	26	24½	Lake silts.
19	M. W. Richmond	26	18	.....	31	25	Do.
20	A. W. Long.....	26	18	.....	22	20	Do.
21	.....	27	18	.....	16	13½	Lake silts (?) with basalt fragments.
22	.....	27	18	.....	22	21½	Do.
23	Mr. Lang.....	27	18	.....	23	22	0-16, lake silts?; 16-23, basalt fragments.
24	J. A. Pond.....	27	18	21	20	20	Alluvium and lake silts.
25	John Ross.....	27	18	7	21	19½	Lake silts.
26	Mr. Anderson....	27	17	.....	27	20	Do.
27	(Auger hole).....	27	17	.....	20	17	Sandy clay.
28	Do	27	17	.....	20	.....	Sands and moist clays.
29	(Auger hole).....	26	17	.....	19½	.....	0-19, sands and moist clay; 19-19½, tuff.
30	Do.	26	16	.....	16	13	Moist clay (at edge of alkaline pool, Pl. III, C.)
31	Do.	26	16	.....	3	Dry	Loose tuffaceous soil (?).
32	Do.	26	15	.....	7½	Dry	0-6½, silt and sand; 6½-7½, tuff.
33	Do.	26	15	.....	16	12	Silts, sands and clays; 8-9, moist sand containing fresh water shells.
34	Do.	25	14	.....	4	Dry	Loose soil, from decomposed tuff.
35	(Well).....	25	14	.....	26	25	0-25, lake silts; 25-26, tuff.

Digitized by Google

Wells and test holes in Fort Rock, Christmas and Silver Lake Valleys
(Continued)

No. of Well.	Owner.	Location.			Depth in feet.	To water in feet	Material passed through.
		T.S.	R.E.	Sec.			
36	(Auger hole).....	27	17	.....	26	24	Silts, sands and clays.
37	Do.	27	17	.....	7	Dry	0-6, silts and sand; 6-7, tuff.
38	Do.	27	17	.....	5	Dry	0-4, lake silts; 4-5, tuff.
39	Do.	28	16	.....	24	24	0-16, lake silts and clays; 16-24, moist clay.
40	Do.	28	16	.....	5	Dry	0-4, lake silts; 4-5, tuff.
41	Do.	28	16	.....	4	Dry	0-3, lake silts; 3-4, tuff.
42	(Well).....	28	16	.....	15	Dry	Lake silts.
43	F. M. Chrisman..	28	14	22	247	49	0-108, lake silts and sands; 108 - 223, tuff; 223-247, basalt (?).
44	Roy Ward.....	28	14	.....	90	Dry	Lake silts (?).
45	T. J. La Brie....	28	14	.....	15	10	Lake silts (near edge of marsh.)
46	Hayes Bros.....	27	14	.....	10	5	Do.
47	F. M. Chrisman..	28	14	12	12	10—	0-3, black loam; 3-9, sand and pumice; 9-12, clay.
48	Frank Maruska..	27	14	13	14	11—	0-2, sandy loam; 2-3.5, hardpan; 3.5-13, clay and sand mixed; 13-14, sand.
49	J. A. Brown.....	28	14	24	41	38—	0-22, soil and gravel; 22-24.5, white tuff; 24.5-41, sand and gravel.
50	R. O. Reigel.....	27	15	24	27	17.5	0-4, soil; 4-8, coarse sand; 8-9, tuff; 9-24.5, clay; 24.5-25.5, hardpan; 25.5-27, gravel.
51	N. Nash.....	27	16	18	35	3	0-3, soil; 3-10, clay; 10-16, hardpan; 16-16.5, gravel; 16.5-23.5, yellow clay; 23.5-34.5, green clay; 34.5 - 35, black sand.
52	J. M. Carr.....	27	16	19	84	26	0-4, soil; 4-22, blue tuff; 22-32, tuff and sand; 32-40, tuff; 40-42, gravel and sand; 42-82, soft material; 82-84, rock.
53	Allen Bros.....	28	16	1	70	40	0-3, soil; 3-8, gravel; 8-20, white tuff; 20-55, basalt (?); 55-70 white tuff.
54	J. L. Thompson..	26	16	15	30	27	0-0.5, cinders; 0.5-5.5, gravel; 5.5-30, clay.

Digitized by Google

Wells and test holes in Fort Rock, Christmas and Silver Lake Valleys
(Continued)

No. of Well.	Owner.	Location.			Depth in feet.	To water in feet	Material passed through.
		T.S.	R.E.	Sec.			
55	Chas. Mittge....	26	16	21	24	22	0-2, sandy loam; 2-2.5, hardpan; 2.5-7.0, clay and sand; 7.0-24, clay.
56	Wm. H. Ledger..	25	19	21	16	12	0-3.5 sandy loam; 3.5-5.5, hardpan, 5.5 - 10.5, sandy loam; 10.5-11, gravel; 11-12, fine sand; 12-16, lava rock.
57	Wm. Bergstrom..	25	19	30	14	9	0-14, sandy loam.
58	A. F. Davis.....	25	18	24	26	24	0-2, soil; 2-24, lava rock; 24-26, blue tuff.
59	J. C. Green.....	25	19	31	12	9	0-4, soil; 4-5, hardpan; 5-12, volcanic ash.
60	Wellon County Road.....	25	13	27 28	144	140—	0-4, soil; 4-5, hardpan; 5-144, lava rock.
61	Not known.....	27	17	30	20+	20	0-5, soil; 5-20, white tuff.
62	Do.	26	14	.....	32+	32	0-1.5, soil; 1.5-2.5, hardpan; 2.5-32, alternating layers of gravel and dark tuff.
63	F. C. Eickemeyer	26	15	6	284	4	0-33, sand and gravel; 33-35, quicksand; 35-284, tuff with thin layers of cemented sand.
64	A. R. Cyrus.....	27	17	12	51	20	0-40, volcanic ash and sand; 40-50, white chalky formation; 50-51, quicksand.
65	Do.	27	17	12	415	16	0-75, volcanic ash and sand; 75-375, cemented gravel, broken lava and near 375 strata of black volcanic ash; 375-415 solid rock.
66	F. A. Remington.	27	18	17	26	16	0-2, soil; 2-4, hardpan, cemented, gravel, broken lava and volcanic ash.
67	F. A. Watkins...	27	18	21	40	38	0-9, soil; 9-11, sand; 11-15, tuff; 15-40, soil.

Digitized by Google

Numbers 1 to 48 inclusive are from Waring's* report, p. 64.

Data relating to the remainder were obtained in the course of this investigation, and in most cases are furnished by the owners of the wells.

The following notes of interest on some of these wells are added from information given by the owners:

No. 47—The water in this well cannot be lowered materially with a common pitcher pump.

No. 48—A three inch centrifugal pump and 5 h. p. gasoline engine are used for pumping. With three feet of water in the well the pump will drain it in fifteen minutes.

No. 52—This well was dug three feet in diameter, requiring no curbing to a depth of 42 feet, and a small but insufficient flow was encountered in sand and gravel. By drilling down 42 feet further with a 1½ inch drill, a strong flow was struck and the dug portion filled to a depth of 12 feet in a few hours. In 12 hours there was 18 feet of water. Quality good.

No. 53—Well three feet square and curbed to rock. Windmill used for pumping. Quality good but a trifle hard. The following is quoted:

"Water is lower this year than it has been. In normal years the water comes to within 20 feet of the surface. There is a stronger vein 4 feet below our present flow."

No. 54—Water not alkaline to taste. About one-fourth acre of garden is irrigated from the well by use of windmill, and water is pumped for 100 head of stock.

No. 59—Same well as No. 14, but described in more detail.

No. 60—This well is located at Fremont, and both gasoline engine and windmill are used for pumping. Quality of water soft, and very pure. Mr. J. D. Johnson furnished the data for this well, and makes the following statement:

"The wells in this locality all have depths from 130 to 200 feet. The water always comes when the sandy formation is reached. This strata reached the water will rise in the well several feet. In one well a crevice was encountered at 176 feet, water was obtained at 188 feet and rose up to and flowed out at the crevice. Nearly all wells have currents of air blowing from them."

No. 63—This well is discussed at length under "Artesian Supply". Mr. Eickemeyer says:

"In regard to the flow of water, I am quite certain it comes from the crevices in the tuff (throughout) the entire depth of the hole and that a shallow well would not furnish water enough."

See plate No. 7, showing the owner in the foreground and the top of Fort Rock in the background over the flume. The flume conducts about 400 gallons per minute from the pump discharge pipe to the ditch.

*Water Supply Paper 220—Geology and Water Resources of a portion of south-central Oregon, Gerald A. Waring, 1908.

Digitized by Google

Attention is called to the fact that Waring in referring to Christmas Lake Valley includes that part of the valley extending from Seven Mile Ridge west to Fort Rock, which in this report is called Fort Rock Valley. Fort Rock (butte) can be plainly seen throughout the length of the valley, standing above the plain like a veritable fort, and local custom seems to favor this nomenclature.

The following is quoted from Waring as best showing the character of material and the quality of water in these wells:

"Throughout the settled area the soil is composed of sands and sediments, which extend to a considerable depth. No coarse gravels are met. The sink of Peter Creek, which at first glance seems to be a separate valley, is really connected with the main valley by a broad drainage channel to the east of Bunchgrass Butte, and the same fine sediments are found in it as in the main part of the valley. In four of the five wells examined in the sink the water level is 20 to 25 feet below the surface, and the water is of good quality, the electrolytic bridge indicating an alkaline content of 30 to 40 parts in 100,000. The fifth well is in the southwest end of the so-called sink, near the basalt rim. It has been dug 25 feet deep, passing through the usual silts at a depth of about 18 feet, and penetrating the remainder of the distance into decomposed basalt, without finding water.

Several wells along the northern side of "Sucker Flat" (North of Fossil Lake) have also reached the basalt at depths of 10 or 12 feet. A small amount of water of fair quality has been found at this depth. Well No. 9 also reaches basalt at a depth of 11 feet, but its water is much more alkaline than that of the others. Half a mile north of this well basalt has been found only 2 or 3 feet below the surface, although there is no indication in the character of the brush that the soil here is so shallow. As shown by the wells farther south in the flat, the soil in that part is deeper. Basalt has not been found in them at a maximum depth of 31 feet in well No. 19. The ground-water level varies from about 10 feet below the surface near Cliff post-office to 25 feet near Christmas Lake. The material in which water is found varies in texture from sandy to clayey.

South and west of Christmas Lake the waters are as a rule of better quality than in the area near Fossil Lake. In October, 1906, the water level was about 20 feet below the surface and the mineral content was from 25 to 50 parts in 100,000. In all of the wells it has been noticed that on standing for any length of time the water becomes more strongly alkaline and has an odor as of decaying organic matter. In one well, near No. 15, even though in constant use, the water became so strong as to necessitate the digging of another well.

The wells on the south side of the valley show that the sediments thin out there as on the north. Fragmental volcanic material is met near the bottoms of wells Nos. 21, 22 and 23, which, being from 16 to 23 feet deep, are extended only a foot or so below the water level.

West and northwest of Sevenmile Ridge a number of auger holes were put down, which indicate that the tuff exposed in this ridge, in the hills near Table Rock and in Fort Rock, underlies this part of the valley at shallow depths. Some irregularities in its surface have perhaps formed basins, as at test holes Nos. 33 and 39, where water was found at depths of 12 and 24 feet, respectively; but in others a hard material, probably the tuff, was encountered at 3 to 20 feet below the surface.

A short distance south of Fort Rock a well 25 feet deep has been dug, which passes through 25 feet of the usual light-colored silts into the tuff. The water was 1 foot deep in October, 1906, and although it evidently had been standing a long time, contained only 40 to 50 parts of solids in 100,000.

There were no wells in the southeast arm of the valley and no test holes were sunk in it, but Mr. A. W. Long, of Lake, reports having found water at a depth of 15 feet at one point in this area. Its general character indicates water conditions similar to those near Fossil Lake rather than to those of the western part of the valley.

Digitized by Google

ANALYSES OF WATERS

Analyses of three well waters of this valley were made, those of James Wilson (Well No. 12), J. C. Green (Well No. 14) and John Ross (Well No. 25). These show alkaline contents, respectively, of 36.8, 235 and 432.8 parts in 100,000. There is no change in the character of the surface to indicate why the water at Mr. Wilson's should be so much purer than that at Mr. Green's, except that the former is nearer the edge of the valley. In digging Mr. Ross's well a lump of gypsum (sulphate of lime) a foot long and 6 or 8 inches in diameter was found at a depth of 14 or 15 feet (water being struck at 19½ feet); this makes the high percentage of sulphate in this water not surprising. Its mineral character is distinctly appreciable to the taste."

"At the town of Silver Lake water is obtained in the 25 or 30 domestic wells in a soft porous material, usually at less than 30 feet below the surface. This seems essentially a subsurface flow, depending for its supply on the run-off from the surrounding slopes, for in winter, when the mountains are snow covered and the ground is frozen, the water level in the wells lowers. The water is of good quality, tests indicating only about 50 parts of alkaline salts in 100,000.

The only attempt to obtain deep water in the area examined has been made at Silver Lake. Mr. F. M. Chrisman, of this place, put down a 6-inch hole on the south edge of the town at a depth of about 250 feet, where the drill became caught and work was suspended. The usual subsurface water was found at a depth of 47 feet, but no other supply was developed, the drill being fast in dry vesicular basalt. A record of the well as kept by Mr. Chrisman shows a depth of 108 feet of clays, sands and gravels, below which lies a thick tuff bed, probably like that at Fort Rock, underlain by basalt."

Springs.—No springs were observed other than those described by Waring in 1908. In speaking of Silver Lake valley he says:

"On the low slopes of the south side of the valley a few springs have produced green patches of pasture land and furnish watering places for the range animals. The largest of these, Thomson and Murdock springs, 3 miles southeast of Silver Lake, flowed about 9 and 25 miner's inches, respectively, in October, 1906. Their temperature (48°) indicates that they are surface springs, not deep seated, though the water may rise from a porous bed along which it has percolated from the slopes of Hager Mountain."

"Close to the western shore of Christmas Lake there is a well 9 feet deep in which the water stands about 5 feet below the surface. Its temperature in October, 1906, was 62° F., both on cold mornings and at midday. Its mineral content is about 40 parts in 100,000. It is said that originally there was a spring here, but that when the willows and nearby sage were cleared off it was soon buried by sand and was reopened only by digging this well.

Christmas Lake is fed by an intermittent spring at its south end. Fossil Lake is also said to be fed by a spring near its center, from which, it is claimed, range riders have drunk when the lake was dry.

The most interesting springs in the valley are those known as Mound Spring and Sand Springs. These rise in the sands of the area east of Fossil Lake, forming valued watering places for stock. Mound Spring is the larger, having a flow of about 2 miner's inches in October, 1906, which supplied a pond 75 yards across. The water is sulphurous in taste and rises with a temperature of 62° F. Sand Springs, one-third mile northward, are no doubt of the same origin, but the flow is less, being, as nearly as could be measured, about 1½ inches."

Artesian Supply.—It is not known whether artesian water can be found underneath these valleys, as no wells have been sunk through the underlying basaltic bed. The first attempt was made at Silver Lake by Mr. F. M. Chrisman, as

Digitized by Google

described above in Waring's discussion. Within the past two years Mr. F. C. Eickemeyer has made an attempt to get artesian water by drilling a 4¼ inch well about 3¼ miles east of the town of Fort Rock. The drilling was done intermittently as permitted by farm work until a depth of 284 feet was reached, when a large part of the well caved in. Ground water was struck at a depth of about four feet, but no attempt was made to test its flowing capacity until the well caved in, when Mr. Eickemeyer attached a 4 inch centrifugal pump driven by a 6 h. p. distillate engine. He estimates the capacity of the pump at 400 gallons a minute. A test of several hours was made, but the water could not be lowered. A sump was then constructed about six feet lower than the level at which the water stood in the well. After pumping out this sump he allowed water from the well to flow into it with the pump draining from it at the rate of 400 gallons a minute. Noting the time it took the flow of water in the well to gain sufficiently on the pump to fill the sump, Mr. Eickemeyer estimates that the well discharges 600 gallons per minute. This discharge is made through the caved material in the well in addition to about 30 feet of casing. It would thus appear that the owner has succeeded in getting an excellent well for irrigating a small tract of land. Mr. Eickemeyer, who has had considerable experience in sinking wells for artesian water in the south central states, does not claim that he has succeeded in getting artesian water in this well, but states that he will drive a new well of about 12 inch bore to a greater depth and believes he will succeed in getting a true artesian flow.

A great deal of interest has been aroused locally by the apparently large flow of this well, and this will no doubt result in more extensive testing for deep wells throughout the Fort Rock and Christmas Lake valleys. It is hoped that by means of distillate engines or electric power water may be pumped from these wells in quantities sufficient for irrigation use. A great deal of credit is due Mr. Eickemeyer for his pioneering effort in this line.

No extensive geological investigation has been made to determine the existence of an artesian supply underneath these valleys. Waring's investigation of 1908 did not cover the area north and west of the Fort Rock Valley, in which an artesian supply might have its origin. The following is quoted from Waring:

Silver Lake Valley.—"The structure of this basin seems more favorable to the finding of artesian water in the basalts than that of any of the other valleys of Lake County, except perhaps the Christmas Lake desert. On the west and south the slope of the lava beds is toward the valley. To the north also, along the base of Horning Bend, an exposure of tuff indicates that the dip is toward the valley, but on the eastern side this structure is not exhibited. The tuff composing these eastern hills is somewhat folded, but the dips are universally eastward, away from Silver Lake Valley. What effect on artesian conditions this structure may have cannot be stated de-

Digitized by Google

finitely, but the Conley Hills and their extension in each direction probably separate it structurally from that of Christmas Lake Valley. Certainly the structural conditions are such as to justify a thorough test by the drilling of a well, 1,000 to 2,000 feet in depth, in the neighborhood of Silver Lake."

Christmas Lake and Fork Rock Valleys. —"The structural conditions affecting the existence of flowing artesian water in the rocks underlying this valley may be stated briefly as follows: All along the valley's southern border the lava sheets dip uniformly toward the valley at low angles; on the eastern side also the slope is gentle toward the valley. The structure to the north is largely obscured by the recent lava flows, but the older beds appear to be nearly horizontal; as exposed where they form the slopes to the sink of Peter Creek, however, they also appear to dip slightly toward the valley. On the west the Conley Hills and the eastward-dipping tuff ridge near Table Rock probably separate Christmas Lake Valley structurally from Silver Lake Valley. Within the valley itself there are at least two irregularities in the shallow basinlike structure. From Bunchgrass Butte a low basalt ridge extends southward toward the projecting scarp on the opposite side of the valley, and in Sevenmile Ridge there is a similar low peninsula-like ridge, but of tuff, pointing toward isolated blocks of the same material on the north side of the valley.

From these features it appears that in addition to the general low synclinal structure of the valley as a whole there is also a tendency toward folding along axes trending north and south. If this interpretation is correct the valley is divided into three shallow basins, the eastern basin being that of Fossil Lake, the central that of Christmas Lake, and the third the desert west and northwest of Sevenmile Ridge.

These minor secondary folds probably do not affect the likelihood of the existence of artesian water, for they are slight, and tend only to divide the valley, not to prevent the percolation toward it of deep water. The valley as a whole is a structural trough, and therefore the chances of obtaining deep water under pressure seem favorable. The absence of extensive faulting is also a condition which is favorable to the presence of rock water under pressure and which was not found in the southern valleys.

As before stated, the temperature of Mound Spring is 62°, while the mean annual temperature of the valley is about 44°. Assuming the usual increase of temperature with depth as 1° F. for each 50 feet, the water of this spring probably rises from a depth of 900 feet.

The presence of this warm spring, and possibly also the same temperature of the well at Christmas Lake, must be taken as indicating that deep water under pressure does exist under this valley.

The Pauline (Paulina) Mountains lie about 30 miles north of Christmas Lake Valley. About the same distance west of Silver Lake Valley is the Walker Range, an eastern spur of the Cascades. Neither of these ranges was visited, but they are thought to consist of the same series of basalts that cover most of Lake County, and it seems not improbable that the rocks dip from them toward Christmas Lake and Silver Lake Valleys, and that an underground water supply such as exists in central Washington may reach these valleys from those sources.

On the whole, while the data concerning the underground conditions within these two valleys are meager, the indications in favor of the existence of deep waters are sufficient to warrant the sinking of test wells."

Gaging Stations and Records of Flow.—In the winter of 1904-05 the U. S. Geological Survey established gaging stations on the three streams entering Paulina Marsh. The Silver Creek station, established December 29, 1904, is located about a mile and a half southwest of Silver Lake (town) at a narrow place in the gorge. See Sheet No. 37.

On January 21, 1905, stations were established on Bridge and Buck Creeks at the bridge crossings, the one on Bridge

Digitized by Google

Creek being two miles west of Silver Lake (town) and the one on Buck Creek about three miles northwest of the town of Silver Lake, where Buck Creek leaves its canyon to enter Paulina Marsh. Descriptions of these gaging stations may be found in Water Supply Paper 176 of the U. S. Geological Survey.

A gaging station was established on the Sycan River above Sycan Marsh near the "ZX" ranch on May 2, 1915, and daily gage heights were kept until October 12 of that year. A description of this station may be found in Water Supply Paper 177 of the U. S. Geological Survey. In addition five miscellaneous measurements each were made of Long and Coyote Creeks between March 15 and July 31 of the year 1905. Measurements of Sycan River above the marsh were also made March 16 and April 10, prior to establishing the station.

Following is a tabulation of the monthly discharges of these streams taken from the U. S. Geological Survey published records of stream measurements and from unpublished information furnished by Fred F. Henshaw, District Engineer, Water Resources Branch of the U. S. Geological Survey, with offices in Portland, Oregon. The seasonal year, beginning October 1 at close of irrigation, when the accumulation of storage water is begun for the ensuing year, and extending to September 30 of the following year. is used in the tabulation.

Digitized by Google

Monthly Discharge of Silver Creek near Silver Lake, Oregon, for 1905-1915
Drainage Area—180 square miles

Month.	Discharge in Second Feet.			Total Run-off in acre feet.
	Max.	Min.	Mean.	
1905				
January	70	24	36.8	2,263
February	137	21	43.9	2,438
March	155	54	73.9	4,544
April	203	46	89.9	5,349
May	87	27	47.2	2,902
June	39	21	27.8	1,654
July	21	13	16.7	1,027
August	19	15	17.1	1,051
September	19	15	15.4	916
The period (273 days)..	203	13	40.6	22,140
1905-06				
October	21	15	15.7	965
November	42	13	21.4	1,273
December	36	13	21.6	1,328
January	50	17	24.2	1,490
February	78	7	27.8	1,540
March	210	10	40.4	2,480
April	530	57	320	19,000
May	245	43	118	7,260
June	107	21	45.8	2,730
July	21	12	15.4	947
August	15	12	12.8	787
September	15	12	12.6	750
The year	530	7	56.0	40,550
1906-07				
October	13	12	12.1	744
November	26	5	12.9	768
December	102	5	20.5	1,260
January	57	13	37.2	2,380
February	720	57	187	10,400
March	*1400	31	192	11,840
The period (182 days)..	1400	5	76	27,390
1908-09				
January	210	19	55.1	3,390
February	107	15	41.6	2,310
March	199	22	77	4,730
April	337	107	222	13,200
May	368	48	133	8,180
June	48	19	27.5	1,640
July	26	13	17.3	1,060
August	15	11	12.0	738
September	15	11	12.5	744
The period (273 days)..	368	11	66.0	35,990

*Estimated discharge on March 10th, Gauge Height, 9.08.

Digitized by Google

Monthly Discharge of Silver Creek—cont'd.

Month.	Discharge in Second Feet.			Total Run-off in acre feet.
	Max.	Min.	Mean.	
1909-10				
October	15	11	12.8	787
November	865	11	126.0	7,500
December	80	15	43.4	2,670
January	194	15	49.4	3,040
February	282	38	66.1	3,670
March	473	157	311	19,100
April	344	76	150	8,930
May	84	29	46.4	2,850
June	29	22	23.6	1,400
July	24	17	18.5	1,140
August	17	15	15.5	953
September	41	15	18.3	1,090
The year	865	11	73.2	53,130
1910-11				
October	17	15	15.3	941
November	24	15	17.3	1,030
December	35	11	22.2	1,360
January	.....	.....	*13	799
February	.....	.....	*12	666
March	352	.....	85.6	5,260
April	576	122	269.0	16,000
May	323	127	180	11,100
June	117	38	54	3,210
July	38	22	27.1	1,670
August	24	22	23.3	1,430
September	29	20	23.2	1,370
The year	576	11	62.0	44,840
1911-12				
October	26	20	22.5	1,380
November	24	20	21.7	1,290
December	.....	.....	*17.8	1,090
January	152	15	32.3	1,990
February	132	20	41.9	2,410
March	52	17	25.5	1,570
April	188	41	73.7	4,390
May	309	117	199	12,200
June	117	26	44.1	2,620
July	29	13	20.6	1,270
August	15	15	15.0	922
September	17	14	15.1	898
The year	309	13	44.2	32,000

Digitized by Google

Monthly Discharge of Silver Creek—cont'd.

Month.	Discharge in Second Feet.			Total Run-off in acre feet.
	Max.	Min.	Mean.	
1912-13				
October	15	13	14.6	898
November	24	15	18.8	1,120
December	19	11	14.3	879
January	15	11	12.9	793
February	26	8	12.3	683
March	127	8	22.2	1,360
April	337	35	210	12,500
May	322	45	145	8,920
June	45	22	29.6	1,760
July	22	14	17.8	1,090
August	16	14	15.2	935
September	16	14	14.6	869
The year	337	8	43.9	31,800
1913-14				
October	16	12	14.1	867
November	22	10	14.7	875
December	20	7.8	9.99	614
January	52	8.5	20.0	1,230
February	10	8.5	9.46	525
March	350	14	180	11,100
April	350	115	244	14,500
May	115	33	66	4,060
June	33	20	25.7	1,530
July	20	12	15.3	941
August	12	11	11.2	689
September	14	11	12.1	720
The year	350	7.8	52.0	37,700
1914-15				
October	14	10	13.3	818
November	14	10	11.9	708
December	10	.....	7.64	470
January	.....	.....	8.0	*492
February	.....	.....	14.2	789
March	91	13	40.3	2,480
April	82	25	42.7	2,540
May	42	21	28.1	1,728
June	24	.....	19.1	**1,136
The period				11,161

*Estimated.
**Four days estimated.

Digitized by Google

Monthly Discharge of Buck Creek, near Silver Lake, Oregon, for 1905-1910. (broken)

Drainage Area—110 square miles

Month.	Discharge in Second Feet.			Total Run-off in acre feet.
	Max.	Min.	Mean.	
1905				
January	23	12	*15.0	922
February	50	9	18.4	1,020
March	29	4	9.3	572
April	19	8	10.2	607
May	52	17	28.2	1,730
June	55	27	44.2	2,630
July	27	6	11.0	676
August	6	4	4.6	283
September	4	3.5	3.78	225
The period (273 days)..	55	3.5	15.9	8,660
1905-06				
October	8	5	6.0	369
November	7	2	4.77	284
December	7	2.5	5.74	353
January	.....	.....	*8.00	492
February	35	4	11.1	616
March	60	4	17.5	1,080
April	33	9	21.9	1,300
May	77	21	42.6	2,620
June	83	33	58.9	3,500
July 1-19	65	6	34.5	2,120
The period (292 days)..	83	2	22.0	12,730
1909				
January	249	6	44.3	2,720
February	213	4	33.0	1,830
March	31	9	15.4	947
April	40	19	30.7	1,830
May	65	35	51.1	3,140
June	77	40	59.5	3,540
July	35	9	20.9	1,290
August	6	4	4.9	301
September	4	4	4.0	238
The period (273 days)..	249	4	29.1	15,840
1909-10				
October	6	4	4.5	277
November	281	6	34.4	2,050
December	35	9	17.0	1,050
January	129	6	19.6	1,210
February	281	4	43.8	2,430
March	227	31	64.7	3,980
April	60	23	34.9	2,080
May	65	50	61.3	3,770
June	65	23	48.7	2,900
July	35	.....	15.7	965
August	.....	.....	*4.0	246
September	.....	.....	*6.0	257
The year	281	4	29.4	21,315

*Estimated.

Digitized by Google

Monthly Discharge of Buck Creek—cont'd.

Month.	Discharge in Second Feet.			Total Run-off in acre feet.
	Max.	Min.	Mean.	
1910				
October	10	.....	9.7	596
November	21	10	13.4	797
December	14	6	12.6	775
The period 92 days)	21	.....	11.9	2,168

*Estimated.

Monthly Discharge of Bridge Creek, near Silver Lake, Oregon, for 1905-1906
Drainage area—53 square miles.

Month.	Discharge in Second Feet.			Total Run-off in acre feet.
	Max.	Min.	Mean.	
1905				
January 21-31	8.1	2.0	4.55	99
February 1-19, 24-28	10.0	1.2	4.33	206
March	2.8	1.2	2.23	137
April	6.6	.8	2.53	151
May	12.9	1.3	7.79	479
June	15.2	3.0	10.6	631
July 1-6	3.0	.6	2.18	26
August 7-31	.8	.2	.46	23
September	.7	.6	.66	39
The period	15.2	.2	4.10	1,791
1905-06				
October	.9	.6	.73	45
November	1.5	.7	.95	57
December*	1.3	.2	1.00	61
January*	.....	.....	2.00	123
February*	.....	.....	3.00	167
March*	.....	.....	8.3	510
April	23.0	7.0	10.5	625
May	29.0	14.0	21.3	1,310
June	22.0	16.0	18.9	1,120
July 1-21	25.0	6.0	14.0	583
The period	29.0	.2	7.77	4,600

*Ice conditions, discharge partly estimated.

Digitized by Google

Monthly Discharge of Sycan River above Sycan Marsh, near Silver Lake, Oregon

Drainage area—124 square miles.

MONTH.	Discharge in Second Feet.			Total Run-off in Acre Feet.
	Max.	Min.	Mean.	
1905				
March	85	35	*50	3,070
April	220	55	*140	8,330
May	192	97	146	8,980
June	155	34	75	4,460
July	33	10	18.9	1,160
August	10	0	2.87	176
September	14	6	9.67	575
October	24	5	13.4	824
The Period (245 days)				27,600

*Daily discharges for March and April partly estimated.

Miscellaneous measurements of streams entering Sycan Marsh.

Date.	Stream.	Hydrographer.	Discharge in second feet.
1905			
March 16	Sycan River above Sycan Marsh	Ivan Landes	38
April 10	Do	" "	110
March 15	Long Creek above Sycan Marsh	" "	33.6
April 10	Do	" "	54.6
May 1	Do	" "	68.1
June 12	Do	" "	58.6
July 31	Do	" "	18.6
March 15	Coyote Creek above Sycan Marsh	" "	4.2
April 10	Do	" "	8.2
May 2	Do	" "	5.9
June 12	Do	" "	1.7
July 31	Do	" "	.6
1915			
March 19	Sycan River above Sycan Marsh	W. R. Parkhill	31
March 20	Chocktoot Cr. above Sycan Marsh	" " "	13.5

Digitized by Google

EARLY INVESTIGATIONS AND SURVEYS

United States Reclamation Service—Lands, 1904.—In the summer of 1904 an investigation was made to determine the feasibility of irrigating desert lands in the Fort Rock, Christmas Lake and Silver Lake valleys by water diverted from the head of Deschutes River. The plan as worked out, after completing field work to determine storage sites and a route for a canal line, proposed storage in Odell and Crescent Lakes and in Big Marsh at the head of East Fork of Deschutes or Little River, and also diversion of the summer flow of the east fork of East Fork above the canal crossing of this stream. The necessary canal line had a total length of approximately 80 miles from Odell Lake to the center of the lands which it was proposed to irrigate, and in crossing the lowest divide of the Walker Range, separating the upper Deschutes Valley from Fort Rock Valley, required about 4,300 feet of tunnel. The soil through which a greater part of this long canal would be constructed is of the light pumice formation so common to this region, and canal losses were estimated to be so great that possibly three-quarters of the water diverted would be lost. The great length of canal and the excessive seepage losses assumed resulted in an estimated acre cost too great for further consideration. It may be added that since this investigation, made in 1904, practically the entire summer flow coming from the sources proposed has been appropriated for irrigation and power in the Deschutes Valley. See Deschutes Project report. Storage is planned at Crescent Lake for a project in the vicinity of Lapine, now being undertaken by the Morson Land Company, successor to the Deschutes Land Company. It is practically certain that ultimate irrigation and power development in the Deschutes basin will require all the run-off of Deschutes River even with storage. Following the Deschutes Project investigations, all unappropriated waters of Deschutes River which may be stored in Benham Falls reservoir and the regular flow were withdrawn from further appropriation by the State Engineer. See Deschutes Project report, "Land and Water Withdrawals."

During the investigation of 1904, Christmas Lake appeared from Aneroid barometer readings to be about forty feet lower than Silver Lake, and it was thought Silver Lake might possibly be used as a storage reservoir for irrigating lower lands in the Christmas Lake Valley, which were believed to have slope enough for irrigating by a gravity system. Accordingly topography was taken at the Paulina Marsh inlet and at the gap between Silver Lake and Thorn Lake to determine the feasibility of constructing dykes to utilize Silver Lake as a reservoir. Such plan would necessitate pumping Paulina Marsh drainage waters into the lake. The topography developed has been useful in the present investigation.

Digitized by Google

The diversion of Sycan Marsh streams across the divide into Silver Lake drainage was considered at this time, and a gaging station was subsequently established and maintained by the Reclamation Service on Sycan River above the marsh. See "Gaging Stations and Records of Flow." Frequent measurements of Long and Coyote creeks were made at this time.

United States Reclamation Service, Jacobs, 1908 (unpublished).—In 1908 the U. S. Reclamation Service made a further general investigation of irrigation projects in Central Oregon east of the Cascade Range. In connection with this investigation Joseph Jacobs made a rapid reconnaissance in the vicinity of Silver Lake, in which consideration was given, for the first time, to storage on the three streams entering Silver Creek. Mention is made of storage at Thompson Valley and at the Egli site, both on Silver Creek, of the Owsley site on Bridge Creek, and of the Emory site on Buck Creek; also of the possibility of diverting the head waters of Buck Creek into Antelope Flat for storage. No detailed surveys were made, however, and such estimates as were made were based on hand level observations and only approximate measurements. Consideration was given to the use of Silver Lake for storage, involving pumping through a small canal lift for distributing purposes, but it was concluded that any advantage to be gained in the matter of cost over storage on the separate streams would be more than offset by the greater loss through evaporation from such a large water surface, approximately 10,000 acres.

United States Geological Survey, Waring, 1908.—During the season of 1907 Gerald A. Waring conducted a reconnaissance survey of a greater part of Lake County, which includes nearly all of the territory included in the present investigation. The results of his investigation are embodied in a report published in 1908, entitled "Geology and Water Resources of a Portion of South-Central Oregon." Copies of this report are now difficult to obtain, and many quotations from it are therefore included herein, especially information relating to geology, underground water supply and wells. Topography sketched by Waring throughout the valleys under consideration has been of much value in filling out the general topographic map in this report, especially of those areas not covered by surveys during the field work undertaken for this investigation. If possible to obtain, Waring's report should be read in conjunction with this.

United States Geological Survey, Henshaw, 1912.—Fred F. Henshaw, District Engineer of the U. S. Geological Survey, made a "Preliminary Report on Water Resources of Klamath Indian Reservation" in 1913, based on field examinations in 1911 and 1912 and on data collected at other times in connection with

Digitized by Google

stream gaging work. This report has been of much value in this investigation, particularly with reference to studies of comparative run-off from streams entering Sycan Marsh, and the discussion of possible diversions from Sycan Marsh tributaries to Silver Creek for use on lands in Silver Lake and Fort Rock Valleys.

Digitized by Google

INVESTIGATIONS FOR THIS REPORT

Field investigations for this report were begun early in October, 1914, and extended through November, when weather conditions made it impracticable to continue the work.

It was early realized that the water supply of the three streams entering Paulina Marsh would not be adequate, even with storage on those streams, for more than the marsh itself and possibly part of the bordering slopes. Accordingly the first investigation considered was the possibility of diverting the waters of Sycan tributaries into Silver Creek by diversion canal from the streams or possibly by siphon from Sycan Marsh. Investigation of storage on Silver Creek for these diverted waters and for the Silver Creek waters followed.

In this investigation Mr. Parkhill was in charge of a party consisting of Clifford Jessup, topographer, K. H. Minor, levelman, two rodmen, one teamster, who acted as a rodman when not engaged in moving camp or hauling supplies, and a cook. The camp equipment consisted of three 12 by 14 tents, a light cooking range and the usual cooking utensils.

No accurate reference to set level datum of the U. S. Geological Survey was available for use in this investigation nearer than a line of precise levels run from Ashland to Prineville, Oregon, by way of the upper Deschutes River. However, a bench mark of the Oregon Eastern Railway survey, located about three miles north of Seven Mile Ridge, furnished a reasonably accurate datum. The level lines run in connection with this railroad survey connected a bench mark of the U. S. Geological Survey precise level at Ontario, Oregon, and a bench mark on the precise level line between Ashland and Prineville, mentioned above. The number of preliminary and location lines run during this survey and their closing in at frequent intervals made it possible to eliminate any large errors in single lines. Consequently the adjustment of the closing error, which it is thought could be only cumulative throughout the lines, provides a reference to sea level datum probably not more than a few feet in error.

From this bench mark of the Oregon Eastern Railway survey a level line was run to Silver Lake (lake) and from Silver Lake to the town of Silver Lake, where a bench mark was set at the southeast corner of the Leader building. From this point a level line was run west along the county road to the Emory ranch on Buck Creek for use in the survey of the Emory reservoir site. A level line was also run from the town of Silver Lake south along the road to Sycan Marsh as far as the edge of the Thompson Valley reservoir site, where a bench mark was set. See Sheet No. 22. Plane table topography connects this with Sycan Marsh. See Sheet No. 20.

Digitized by Google

From Silver Lake a level line was run south along the county road to the highest of the Ana River springs. A survey of the Ana River Project was made in April, 1905, by Ivan Landes, of the U. S. Reclamation Service, but at that time there were no bench marks available for reference to either the U. S. Geological Survey or to the railroad survey levels. Taken in connection with this survey the level line to Ana River Springs establishes the elevation of Summer Lake in April, 1905, at 4,285 feet above sea level, or 150 feet lower than Silver Lake.

A level line was run north from Silver Lake along the main road to Fort Rock as far north as a schoolhouse three and one-half miles south of Fort Rock. In the spring of 1915, a level line was run from near Seven Mile Ridge east to Lake post-office, thence north to Christmas Lake. Another line was run from near Seven Mile Ridge west to Arrow post-office, thence northwest following roads skirting the foot of the Conley Hills to the schoolhouse three and one-half miles south of Fort Rock, connecting up with the line from Silver Lake, thence north to Fort Rock. Other lines were run about three miles west, north and east from Fort Rock.

In running these level lines turning points were set about every mile and located with regard to section corners for later use in sketching topography and for reference in tying in topographic lines.

From "Early Investigations and Surveys," discussed above, and local information obtainable, it seemed that any extensive project in the locality would involve, first the irrigation of the sloping lands around Paulina Marsh, with possibly the reclamation of the marsh itself, and second the extension of the project to cover some of the lands of the Fort Rock Desert lying northeast from the Thorn Lake gap.

The feasibility of the latter scheme depended on the depth and fertility of the soil and whether there was slope enough to make distribution of water to farms practicable. Also the cost of building a canal from a diversion point on Silver Creek to Silver Lake, thence around the west, south and east sides of the lake, or by crossing the inlet from Paulina Marsh by a long flume or a pipe line siphon, would be a controlling feature.

The elevations found by the level lines run throughout Fort Rock Valley and the western end of Christmas Lake Valley indicated a generally level plain varying but a few feet in elevation. This made it appear impracticable to distribute water by a gravity system aside from questions of drainage. Office studies in the winter of 1914-15 showed that the cost of the main feed canal to reach this area would be prohibitive on account of the high cost of building a siphon about 8,000 feet long, required across the Paulina Marsh inlet. It thus appeared that the sloping lands

Digitized by Google

bordering the Fort Rock Valley toward its western end would offer the best possible extension of any project beyond the sloping lands bordering Paulina Marsh. A canal line was therefore surveyed, early in 1915, over the low pass from Paulina Marsh to the west end of Fort Rock Valley and thence north along its western slope. Topography was taken for a distance on either side, to a point a few miles northwest of Fort Rock. A canal line survey was also made from Buck Creek, at the pass elevation, along the western slope bordering Paulina Marsh to the pass.

RESERVOIR SITES

Thompson Valley.—The Thompson Valley reservoir site is located on Silver Creek about 12 miles south of Silver Lake. See Sheet No. 38. There was no information available for this site other than mention of it in earlier investigations as a possible location.

This site is an open valley of about 5,000 acres located between the foot-hills of mountains on its east and west sides, and is separated from Sycan Marsh on the south by a low divide about 50 feet above Thompson Valley. See Sheets Nos. 20 and 22.

A great many small streams enter from the west side and from the southeast. The tributary area is practically all timbered. The east side of the valley is formed by a low bench about 50 to 75 feet high, while the west side rises gradually into the higher timbered slopes. The Middle Fork of Silver Creek and Silver Creek leave the valley through two narrow canyons and join about half a mile north.

Topography of these two canyons taken to their junction indicates that a dam at that point will have to be about 150 feet high to obtain the storage estimated to be required. A ridge extends between the two dam sites hereafter referred to as East dam site and West dam site, with a low depression about half way between them at the 5,100 foot contour. An approximate estimate of the capacity of the reservoir at the elevation of this depression is 75,000 acre feet and of the area 4,500 acres. This is estimated to be sufficient for storage of all waters of Silver Creek entering Thompson Valley, and any waters which might be diverted from the Sycan Marsh drainage area. Topography was taken over the entire area to an elevation about ten feet above this depression.

A plane table survey of this site was made on a scale of 1,000 feet to the inch, with horizontal control based on plane table triangulation and vertical control from the level line run from Silver Lake heretofore referred to. See Sheet No. 22. A survey of the main, or east, dam site, was made on a scale of 200 feet to the inch and is incorporated in the plan of the East dam

Digitized by Google

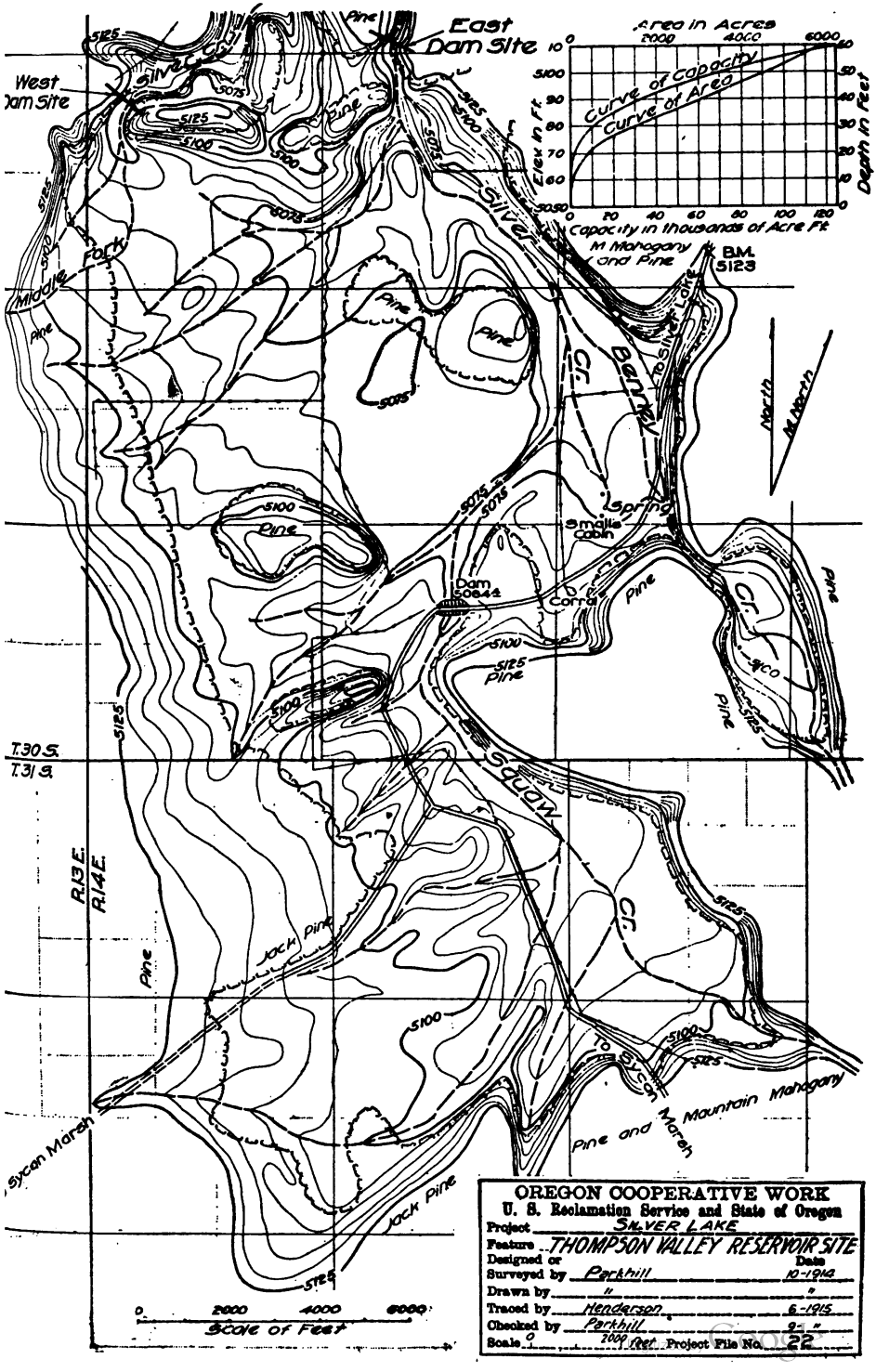
shown on Sheet No. 24. Topography on this scale was taken of the canyon about half a mile further down Silver Creek to include the junction with Middle Fork of Silver Creek. The fall in Silver Creek in this half mile is 100 feet. Consequently a dam below the junction to take the place of the two proposed dams would have to be 100 feet higher than the East dam and clearly is not to be considered. Topography for the West dam was taken in surveying the reservoir site and is shown in more detail on Sheet No. 24. No test borings were made at the dam sites.

Emory Site.—The Emory reservoir site is located on Buck Creek about six miles west of Silver Lake. It is formed by the widening of the Buck Creek Canyon for a distance of about two miles to an average width of about half a mile. The Emory ranch is located in this reservoir site and gives it the name. Buck Creek leaves this site through a narrow "V" shaped canyon with rock walls. A ridge from this narrow canyon, extending to the south, forms a natural embankment at the lower end of the reservoir site, and is the controlling elevation to which storage may be developed. The Silver Lake—Klamath Falls road passes through the low place in this ridge about 1,000 feet south of the dam site at an elevation of 4,642 feet. Storage capacity at this elevation will be about 14,000 acre feet and cover an area of 600 acres. No survey had previously been made of this site, although Jacobs had roughly estimated the possible storage capacity during his investigations in Central Oregon in 1908. A survey was made of this site on a scale of 400 feet to the inch, as shown on Sheet No. 23. No separate detailed topography was taken of the dam site and no test borings made.

Egli Reservoir Site.—This site is located on Silver Creek two miles southwest of the town of Silver Lake, in Sections 28 and 33, T. 28 S., R. 14 E. See Sheet No. 26. The basin which forms it is about a quarter of a mile wide and one and a quarter miles long. The Egli ranch is located in this site and gives it the name.

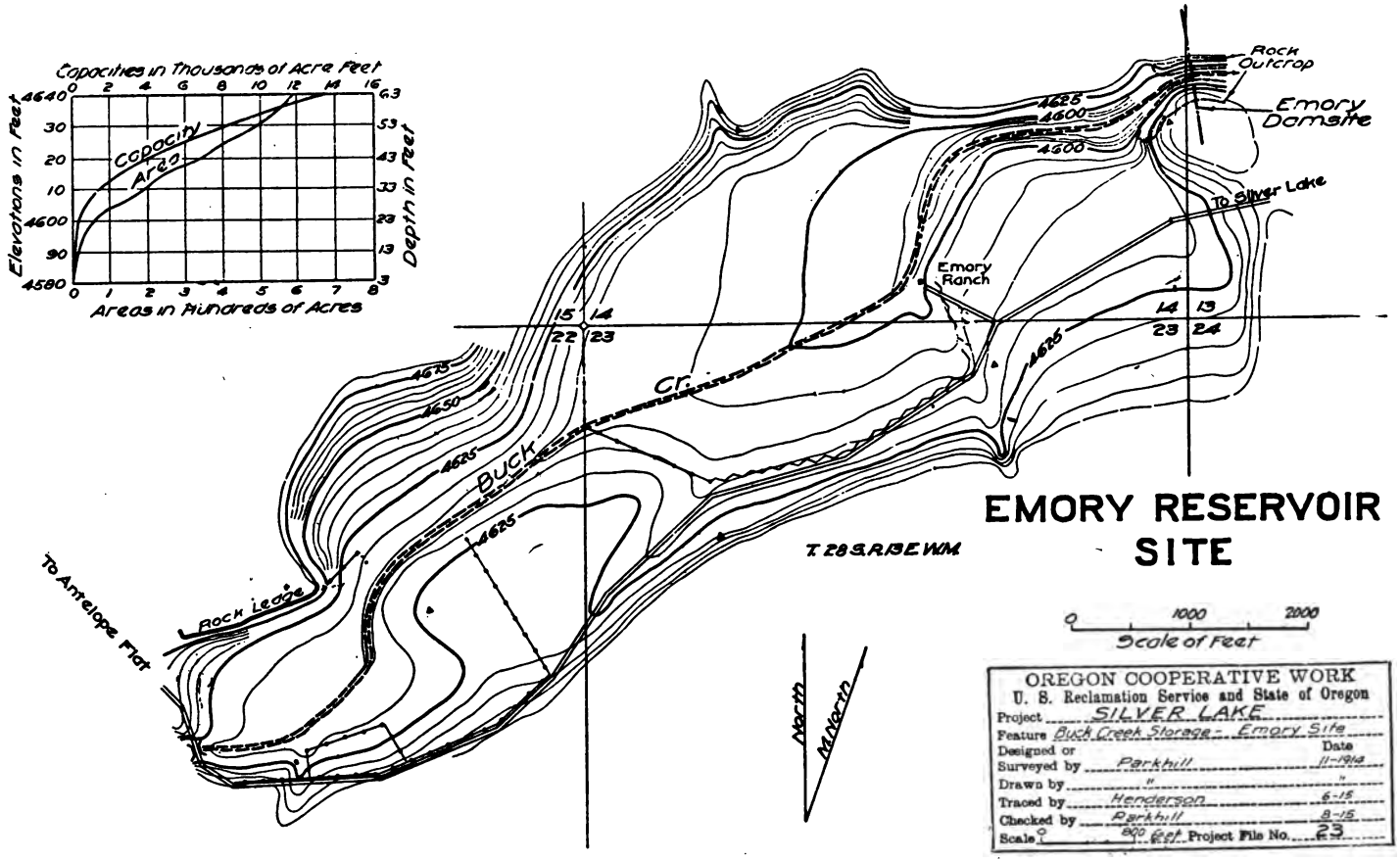
Silver Creek enters the basin at the south end from a "V" canyon cut in a rim rock ledge extending north and south. The basin narrows to a gorge to the north end, through which Silver Creek flows to a point west of the town of Silver Lake, where it reaches the level of the surrounding marsh border. The upper end of this gorge is the site of the present gaging station. Lava rock outcrops on either side of the canyon and forms a favorable dam site. This formation of rock may be seen extending in a ridge southeasterly from the dam site. The main road south from Silver Lake to Thompson Valley passes through a depression in this ridge. The basin forming the reservoir site appears

Digitized by Google



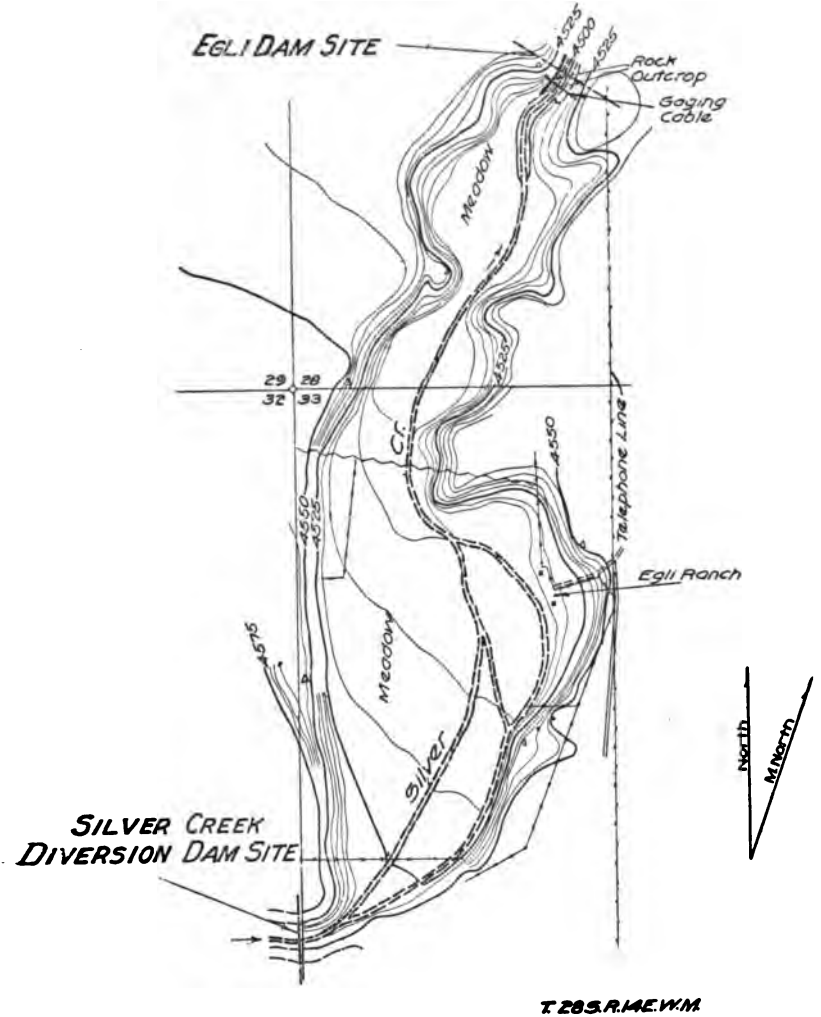
OREGON COOPERATIVE WORK	
U. S. Reclamation Service and State of Oregon	
Project	SILVER LAKE
Feature	THOMPSON VALLEY RESERVOIR SITE
Designed or Surveyed by	Parkhill — Date 10-1912
Drawn by	" — "
Traced by	Henderson — 6-1915
Checked by	Parkhill — 9- "
Scale	0 2000 Feet — Project File No. 22

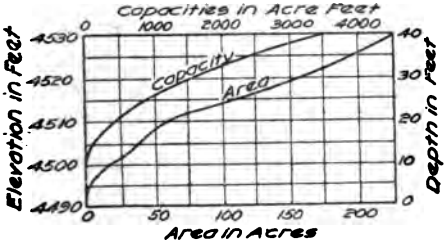
Digitized by Google



Digitized by Google

Digitized by Google





T. 28 S. R. 14 E. W. M.

0 800 1600 2400
Scale of Feet

OREGON COOPERATIVE WORK	
U. S. Reclamation Service and State of Oregon	
Project	SILVER LAKE
Feature	Silver Creek Storage - Egli Site
Designed or Surveyed by	Parkhill — Date 6-15
Drawn by	Henderson — "
Traced by	" — "
Checked by	Parkhill — "
Scale	800 Feet — Project File No. 26

Digitized by Google

Digitized by Google

to have been cut out of the softer and more decomposed rock between the ridges referred to above, probably by the shifting back and forth of the stream channel during the time when Silver Creek was cutting down and forming the canyon which is the present outlook from the basin.

It is not believed that this site would prove economical for storage alone, as it covers only 250 acres at the maximum development to the general level of the bench at the dam site and would be only 40 feet deep at that place, with a storage capacity of but 3,500 acre feet.

The dam site at the lower end seemed a favorable place for a diversion dam for the Silver Lake Unit lying between this reservoir site and Silver Lake along the south slope of Paulina Marsh.

The storage supply for this reservoir would come below Thompson Valley from lower Silver Creek and the West Fork of Silver Creek, which have a drainage area of about 75 square miles. It would be available for use on the present hay lands of Paulina Marsh after diversion had ceased each season through the canal diverting at the top of the dam forming the reservoir. With this in view topography was taken of the site on a scale of 400 feet to the inch, and plane table triangulation used for horizontal control. No survey had previously been made of this site.

An estimate was made for a diversion dam to be located at this site near the present gaging cable. The dam estimated was of the earth and rock fill type, with spillway at an elevation of 4,526 feet. The cost of dam, with that of reservoir lands added, brings the total cost, considered only as storage, to about $22.00 per acre foot stored. With the maximum storage development possible at this site reaching an elevation of 4,530 feet with a dam 45 feet high, and a storage capacity of 3,500 acre feet, it is believed the acre foot cost would be if anything in excess of $22.00 per acre foot stored.

It may thus be seen that the Egli Reservoir site, considering its value for storage only, is not feasible in case of a diversion duty of as much as 1.5 acre feet per acre. This is believed to be the minimum diversion duty practicable for lands along the marsh border which this storage would serve.

Other Sites.—Other reservoir sites in the Silver Lake drainage area which are often locally referred to, and which were investigated by the United States Reclamation Service in 1908, are the Owsley site on Bridge Creek and the Antelope site about twelve miles west of Silver Lake. See Sheet No. 37. This latter site is not on Buck Creek proper but can be utilized for storing its head waters by constructing a few miles of feed canal.

Digitized by Google

Owsley Site.—This site is located on Bridge Creek in Sections 25, 26, 35 and 36, in Township 28 South, Range 13 East. The site is formed by the widening of the Bridge Creek canyon for a distance of about two miles. The estimated storage capacity is about 5,000 acre feet. The area drained through this site is 53 square miles.

The records of flow on Bridge Creek are not very satisfactory. Those which may be considered reliable were made from January 21, 1905, to July 21, 1906. The streams of Central Oregon on which complete records have been kept for a number of years indicate that the seasonal year 1905-06 is only slightly in excess of the mean annual discharge. The discharge of Bridge Creek from October 1, 1905, to July 21, 1906, is 4,600 acre feet. It is estimated that the annual discharge ranges from 1,600 acre feet in 1914-15 to 9,600 acre feet in 1903-04. It will thus be seen that storage at this site to hold back the discharge in the non-irrigating season of a high year would require development to the maximum storage estimated.

The mean annual discharge is estimated at 5,000 acre feet. Of this, 2,000 acre feet would come during the irrigating season and is now largely appropriated. This leaves 3,000 acre feet available for storage and probably about 2,500 acre feet available for use on new lands after seepage and evaporation losses in the reservoir have been deducted.

Under most favorable conditions as to dam site, when a reservoir is of small capacity and the reservoir site is under private ownership and farmed, as in the case of the Owsley site, the cost per acre foot of capacity is excessive, as shown by the estimate of storage cost at the Egli site where conditions are similar. It is believed that storage at the Owsley site would cost not less than $20.00 per acre foot stored. No survey was made of this reservoir site.

Antelope Site. —Antelope Flat, which forms this site, is located in the south-central part of Township 28 South, Range 12 East, and is a broad open prairie of about 3,000 acres. Bear Creek empties into the western end of this flat, and during years of high run-off must have a considerable discharge as evidenced by the well defined channel through the flat and the evidences of flow seen in the canyon at the outlet of the flat where boulders are water worn and packed as if by swift stream action. The outlet canyon where entered from the flat is 160 feet wide, with perpendicular lava rock walls about 40 feet high which afford an excellent dam site so far as abutments for a dam are concerned. No tests were made to determine the character of strata beneath the channel bed.

Information given by A. B. Schroeder, of Silver Lake, Oregon, who assisted on a level line survey made from Thompson

Digitized by Google

Valley to Antelope Flat, indicates that the head waters of Buck Creek may be diverted into Antelope Flat by a canal about five miles long. The area tributary to Buck Creek which might be so diverted is estimated to be 25 square miles. The area tributary to Antelope Flat is estimated to be 40 square miles. The portion of the total drainage area of 110 square miles tributary to Buck Creek which could be controlled by storage at Antelope Flat is thus seen to be about 65 square miles, or 59 per cent. The evaporation losses in a mean year on an estimated average exposed water surface of 1,000 acres would probably be as much as 3,000 acre feet and the seepage loss possibly as great, a total loss of 6,000 acre feet in the reservoir. The inflow would probably not exceed 9,000 or 10,000 acre feet, leaving only 3,000 to 4,000 acre feet available for use.

The Emory reservoir site is therefore believed to be more practicable for Buck Creek storage on account of the smaller water surface area which will be exposed to evaporation and the fact that all the Buck Creek drainage passes through the site.

CANAL LINES

Canal lines in general were run out by plane table survey on a scale of a half mile to the inch, and topography taken on either side to an elevation of about 25 feet above and below the line. Prominent topographic features that came within instrument range were noted as the lines were run. Under this would come creek crossings, road crossings, prominent points of rock, farm buildings, wells, etc. Section corners were found wherever possible for horizontal control, and the compass needle used for bearings.

Elevations were checked from time to time by tying into level turning points heretofore referred to as, when running the level lines, turns were set wherever it was thought they would be useful for the purpose.

Sycan Canal.—Beginning at a low place in the ridge between Thompson Valley and Sycan Marsh located in the S. W. ¼ of Sec. 15, T. 31 S., R. 14 E. (See Sheet No. 20), a canal line was run at about elevation 5,320 feet along the southwestern slope of the Sycan Butte and the east side of the slope bordering Sycan Marsh, to a point on the Sycan River in the S. E. ¼ of Sec. 23, T. 32 S., R. 14 E. A canal line at this elevation would be about 13 miles in length and is probably the shortest diversion line that can be found. Steep, rocky slopes were encountered, however, and the Chocktoot Creek crossing would require a flume about 650 feet long over a canyon some 50 feet deep. Between Chocktoot Creek and Sycan River at this elevation, ledges of basalt and heavy float rock were encountered. The line reached Sycan River Canyon where it was about 100

Digitized by Google

feet deep. Altogether this would be an expensive canal to build. The slope below this canal line became less rocky and the canyons shallower toward the border of Sycan Marsh.

More detail topography was therefore taken along the ridge at the north end of Sycan Marsh to find a lower pass. Such a low pass was found in the N. E. ¼ Sec. 13, T. 31 S., R. 13 E. This proved to be about 40 feet above the surface of the marsh. A canal line was run from this pass along the eastern border of the marsh to the Sycan River in Sec. 22, T. 32 S., R. 14 E. At this point the canyon is not so deep and there would be no unusual difficulties in diverting the water of the river at a point about three-quarters of a mile further up. This canal line will be about 14 miles long but will cost less than the 13 mile canal at a higher elevation.

Long Creek Canal.—From the low pass last mentioned a canal line was run southwesterly along the western slope of Sycan Marsh as far as Long Creek. Three small stream crossings were encountered before reaching Long Creek, the largest being Coyote Creek. The land slopes toward the marsh at the rate of about 20 feet to the mile. There is very little rock in evidence, the stream channels showing a depth of soil in some places of as much as six or seven feet. See Sheets Nos. 20 and 39.

Silver Lake Canal.—The sloping lands lying about the town of Silver Lake and extending from Silver Creek to Silver Lake, hereafter referred to as the Silver Lake Unit, can best be served by a canal diverting from Silver Creek above the Egli reservoir site and following the foot of the rim rock ridges which form the southern limit of good irrigable land.

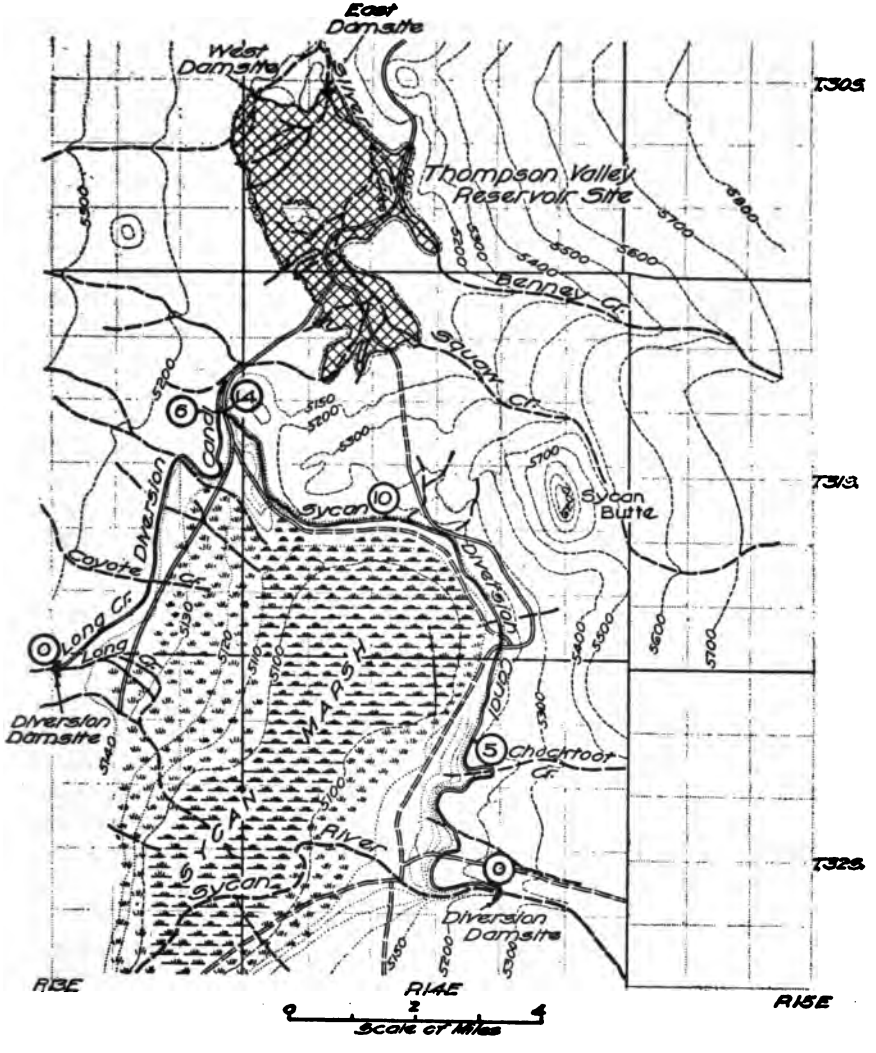
A plane table survey was made along the foot of the ridges referred to and topography taken on either side to determine the best location for a canal line. This topography was taken on a scale of a half mile to the inch, and section corners were located for horizontal control. The survey was extended to the ridge about a mile and a half west of Silver Lake, which is crossed by the main road from Silver Lake to Summer Lake. From this point to the lake, topography had been taken by the Reclamation Service in 1905, in connection with a survey made of the inlet to Silver Lake from Paulina Marsh, to an elevation 50 feet above the lake surface. Taking up this topography about a mile northeast of the bridge over the inlet, canal line topography following about the 4,450 contour was carried along the north slope of Silver Lake to the Thorn Lake Gap and thence north, skirting the foot of Table Rock to a point about two miles north of Thorn Lake. This survey was made in the fall of 1914 when it was thought that the lands in the eastern end of Fort Rock

Digitized by Google

Digitized by Google

Digitized by Google

THOMPSON VALLEY RESERVOIR
AND
FEED CANALS



OREGON COOPERATIVE WORK	
U. S. Reclamation Service and State of Oregon	
Project	SILVER LAKE
Feature	Long Cr. & Sycan R. Canals - Thompson Valley Reservoir Site
Designed or Surveyed by	Birchhill — Date 7-15
Drawn by	Henderson — "
Traced by	" — "
Checked by	Birchhill — "
Scale	0 1 2 4 Miles — Project File No. 39

Digitized by Google

Digitized by Google

Valley would be suitable for irrigation and offer the most economical extension of any project beyond the lands in the Paulina Marsh district. See Sheet No. 19.

West Canal.—In considering the possibility of irrigating the west end of Fort Rock Valley in the country about Fort Rock it was thought a more direct route for a canal line could be found by following the western slope of Paulina Marsh to the pass west of the Conley Hills through which the main road from Fort Rock to Silver Lake runs. The elevation of this pass had been previously determined, by a level line run from Silver Lake north along the road to the pass, to be 4,550 feet. A plane table canal line survey was run from Silver Creek at the Egli Reservoir site northwest at an elevation of about 4,575 feet to Buck Creek, thence along the steep slope of the rim rock to the northwest corner of Township 28 South, Range 14 East. At this point the field work was discontinued on account of severe weather. In March, 1915, the work was again taken up and the line continued, following about the same elevation to the pass above referred to, and thence north along the west slope of Fort Rock Valley at approximately 4,550 feet elevation to a shallow canyon about one and a half miles northwest of Fort Rock, which is the outlet from a basin to the west in which the town of Fremont is located.

No plane table topography was taken along the north and northeast slopes of Conley Hills for a canal to serve the lands on these slopes hereafter referred to as the Horning Bend Unit. However, the upper limit of the gentle slope and the foot of the steeper slope were sketched in and a level line run along the road at the lower limit of the gently sloping lands which have been mentioned in connection with description of level lines. This gave the necessary information for sketching in topography, as shown on Sheet No. 19.

IRRIGABLE LANDS—TOPOGRAPHY

Topography taken in connection with running out canal lines generally determines the upper limits of the irrigable lands, which in both the Paulina Marsh and Fort Rock basins are the sloping lands lying between the foothills surrounding these basins and the marsh in the one case, and the low flat bottom of the Fort Rock Valley in the other.

Level lines heretofore described were generally run in or near these bottom lands and furnished elevations by which the contours on the slopes below the canal line were sketched. In some cases, as in the western part of Paulina Marsh and the land lying east from Silver Lake between the main road and the canal line, the hand level was used, elevations being carried

Digitized by Google

either from the level lines or the canal line to intermediate land corners and the topography sketched in Township Plat books.

Where topography was actually taken with the plane table and where level lines occur to establish elevations, contours are shown on the map by continuous lines, otherwise sketched topography is indicated by dashed or broken lines. See Sheet No. 19.

SOIL AND AGRICULTURAL SURVEY

An examination of the soils and investigations of the agricultural possibilities of the project was made by W. L. Powers, Assistant Professor of Agromy, Oregon Agricultural College, in April of this year, and the following chapter has been prepared by him.

Description of Area.—The lands included in the proposed Silver Lake Project are located in Northern Lake County surrounding the towns of Silver Lake and Fort Rock. The land about Fort Rock is gently sloping basin land surrounded on three sides by rough hills. The lands about Silver Lake are low benches and slopes draining to the northeast and southeast into Paulina Marsh. These lands are surrounded by rough stony land which is higher in elevation. The mean elevation of these lands is about 4,475 feet. The whole area includes about fifty thousand acres and may conveniently be considered in four groups, as follows:

The Fort Rock Unit includes 23,000 acres in a fairly compact body of land surrounding the town of Fort Rock and having a slope of about seven feet to the mile in a southeasterly direction. It extends from the higher hills surrounding three sides of it to the flat lands of a former lake bed to the southeast.

The Horning Bend Unit extends southeast from the Fort Rock Unit along the slopes on the northeast edge of the Conley Hills. The land with good drainage included in this unit extends from the rough stony hills out to the flats that are somewhat alkaline. It varies in width from one to two miles and is perhaps ten miles in length. This unit includes 11,000 acres.

The Paulina Unit includes 10,500 acres in a few low benches at the west and north of the Paulina Marsh. The benches are separated by streams entering the marsh.

The Silver Lake Unit includes about 8,500 acres of gently sloping black sage bench land, surrounding and extending east from the town of Silver Lake and having a gentle slope to the marsh which lies north of it.

In addition, the control of this water for irrigation purposes may uncover part of the sandy loam lake bed of Silver Lake and some of the black silt loam which generally underlies the open water in the Paulina Marsh.

Digitized by Google

Climatic Conditions.—The short growing season of this district is probably its greatest limiting factor in crop production. Next to this, the lack of soil moisture is more important than the fertility in determining the productive capacity of this soil. From the Weather Bureau Record it appears that the rainfall at Silver Lake for fifteen years has averaged 11.2 inches and at Fort Rock the five year average is 9.75 inches per year. Light frosts are liable to occur any month, and June frosts frequently reduce the yields of grain or prevent it filling properly. The surrounding hills are not high and the wind sweep is strong enough to be rather objectionable.

Agricultural Conditions.—The earliest type of agriculture in the district was the range stock business. Stockmen were attracted to the wild meadows in the Paulina Marsh, and the sage brush land in the surrounding land was utilized for summer range while the marsh land was cut for hay or inclosed for pasture for winter feeding. Some of the present stockmen in the region have resided there for thirty years or more. Their holdings are rather large farms. The meadow land is valued by the owners at about twenty-five dollars per acre. But little attempt has been made by the stockmen at cultivation. The streams leading into the marsh have been diverted by ditches and wild flooding has extended the area of native meadow. In recent years some small fields of alfalfa and grain have been produced and some hardy roots have been produced by homesteaders adjoining the marsh. The wild hay yields from one-half ton to one ton per acre, the average value being estimated by local farmers at ten dollars per ton. Cattle and horses are the leading kinds of stock that have been kept.

The capital invested in these stock ranches in 1912 ranged from $17,000 to $127,000 per farm. A low rate of interest is realized on the investment according to the farmers' statements, but this might have been due to unfavorable market conditions. Little or no shelter is afforded for stock though this might be profitably provided.

The sage brush land surrounding Paulina Marsh and in the locality of Fort Rock has been taken up as enlarged homesteads during the past seven years. The sage brush has been burned off or grubbed out from the larger part of this area, and perhaps twenty or thirty per cent has been broken up for cultivation to dry-land crops. The land is fallowed one year and cropped to grain the next. No further crop rotation has been practiced.

The prevailing type of soil in the district is a medium, loamy sand and in the area selected for the proposed project has fairly good depth and comparatively good underdrainage. The sur-

Digitized by Google

face is a little inclined to blow but the soil is of a somewhat heavier texture underneath and provides a fairly good soil moisture reservoir.

From information obtained from farmers, we find that the average cost of clearing on twelve farms was $4.50 per acre. In one instance clearing was being done with a homemade sage grubber, consisting of a heavy sled with heavy knives extending out diagonally on either side of the runners. The sled was drawn by a traction engine and the brush piled on the sled to use for fuel in plowing. It was estimated that an acre could be cleared by this method in one hour when working steadily. The tool left the soil loose as though it had been disked.

Statements of the farmers indicate that it pays to fallow and to use the sub-surface packer. The chief difficulties complained of are frost, lack of moisture and wind. The manure produced by the farm stock has been applied to the grain fields or gardens. Rye is the main crop on the dry land. The average yield of rye hay on these ten farms is three-quarters of a ton per acre. The average value is ten dollars a ton. The average yield of rye grain is given as nine bushels per acre. Some of the homesteaders have small herds of cattle. The average number of horses per farm on these ten farms reported was six, and the number of cows two. Most of these ranchers keep poultry for home use.

This is a new homestead country and the farms, as yet, have not been brought into profitable production so the profits to date have been from the livestock business rather than directly from the soil. The average capital invested on these ten farms was $4,261, and but few of these had made a living, or paid operating expenses and kept the family throughout the year. Much attention has been given to clearing and breaking new land and providing buildings for the farmer and his stock.

In addition to hay and stock some dairy products are marketed and some hay is sold. There is now a creamery at Fremont, which is located in the northwest part of the Fort Rock Unit of the project.

Soils.—The soil material was derived from weathering of the basaltic country rock of the region and has been deposited in its present position largely by water action. The larger portion of the project consists of old lake terraces and beds. Over most of this area there is a few inches of loose sand on the surface which has been deposited largely by wind action. The sandy slope next to the hills which surround the basin near the margin of the project in places is several feet deep and gravity has no doubt assisted in transporting the soil material to its present location in the steeper slopes. The benches of higher

Digitized by Google

elevation contain somewhat coarser material, some grit being present in the surface and some gravel in the subsoil. This material was probably deposited by more violent water while the finer material towards the flat part of the basin was perhaps deposited in quieter water. Even the subsoil in places has been reworked by wind. Within the project, and especially east of the project, there are sand dunes and sink holes which have probably been cut out largely by wind action.

From a physical standpoint, the soils are generally free-working and loose on the surface so that they are readily mulched. At the same time, they contain more fine material in the subsoil which makes this subsoil heavy enough to mould in places and gives it a good water-retaining capacity. The texture of the soil is generally suitable for irrigation purposes. Near the outer margins of the project the soil is rather too coarse to be ideal for irrigation farming, and at the lower levels it becomes of rather heavy texture and is a little inclined to crust and become alkaline. The entire area might be divided into (1) the basin floor (2) low slopes and (3) benches. The following table gives the areas of different soils on the project by units:

Approximate Areas of Different Soil Types.

Unit.	Medium Loamy Sand.	Medium to Coarse Loamy Sand.	Medium to Fine Sandy Loam.	Medium Sand.	Dark Fine Sandy Loam.	Black Silt Loam.	Total Area.
Fort Rock.....	16.800	4,100	.....	2,100	.....	.....	23,000
Horning Bend....	1,600	.....	7,000	2,400	.....	.....	11,000
Paulina Unit.....	2,950	5,100	.....	.....	1,550	900	10,500
Silver Lake.....	5,640	2,560	.....	.....	.....	300	8,500
Totals.....	26,990	11,760	7,000	4,500	1,550	1,200	53,000
Per cent.....	50.8	22.2	13.4	8.5	2.9	2.2	.....

Medium Loamy Sand. —About fifty per cent of the proposed project is medium loamy sand. The surface of this soil is inclined to be loose and naturally mulched and contains considerable amounts of the medium and finer grades of sand. There is a small amount of grit present in this soil. The sub-soil usually contains a higher per cent of finer material and would probably classify as medium sandy loam. In places there is enough clay present so that the sub-soil moulds readily. The sub-soil is frequently set a little at a depth of from eighteen to forty-two inches. The average depth to this harder soil would be perhaps two feet. This type generally has a moderate slope which is very favorable for irrigation. In the native state it is occupied by medium-sized, common sage and in flatter places there is some yellow sage mixed with the common black sage or in

Digitized by Google

some places there is a little grease wood or atriplex (nuttallii wats.). The prevailing vegetation is medium sized black sage and a small amount of bunch grass. The soil is light gray-brown in color and is of comparatively uniform texture over the large area that it covers. This is the prevailing type of soil that is cultivated to rye and other dry-farm crops at present and it is regarded as very suitable textured soil for irrigation purposes at this altitude, where a rather warm soil is required. The most promising crops under irrigation would be hardy grain, such as rye, macaroni wheat and emmer; clover and timothy for meadows; and mangels, rutabagas, carrots, rape and field peas. The mechanical analyses of two surface soils obtained in widely separated parts of the area are given in the following table:

Mechanical Analysis of Medium Loamy Sand, Silver Lake Project.

Soil No.	Location.	Coarse Gravel %	Fine Gravel %	Coarse Sand. %	Medium Sand. %	Fine Sand. %	Very Fine Sand. %	Silt. %	Clay. %	Humus. %
Surf	Sec. 23, T. 28, R. 14 E.	10.00	8.40	18.36	10.88	22.40	26.34	9.89	4.11	.48
Surf	Sec. 3, T. 26, R. 14 E.	5.00	5.41	23.36	12.56	19.54	27.72	9.86	2.08	.80

Medium to Coarse Loamy Sand.—The medium to coarse sand is really a coarser phase of the medium loamy sand and occupies the higher benches or terraces in the Fort Rock and Paulina Basin and embraces about 22 per cent of the proposed project. The main areas are on the higher land between Fort Rock and Fremont and on the benches west of Paulina Marsh. There is a little more grit in the surface soil than in the medium loamy sand and the subsoil in places is rather gravelly. Where this is true, antelope brush or winter fat (Eurotia lanata mog) appears. The wood from this brush has not been destroyed by burning off the sage and it still remains on the uncultivated land. Before burning there was apparently considerably more black sage than antelope brush, there being only a small amount of the latter. This land usually lies well for irrigation and has good under-drainage. There is some variation in the depth but usually it is at least as deep as the medium loamy sand. On account of the presence of a small amount of grit in the surface soil, this land is a little less inclined to blow than is the medium loamy sand. On the other hand, its somewhat coarser texture would cause it to have a little lower plant food content perhaps and to require slightly more irrigation water. Otherwise, it is very similar to the medium loamy sand and is regarded as suitable for irrigation purposes.

Digitized by Google

Medium to Fine Sandy Loam. —Medium sandy loam occurs along the lower slopes southeast of Conley Hills in the Horning Bend Unit of the Project. This district has been sheltered from the wind by the Conley Hills and the drainage around the hills follows the lower edge of this area to the southeast toward Thorn Lake apparently, giving rise to a soil of somewhat finer texture and darker color. The land is nearly level and contains mainly medium-sized black sage though in places some yellow sage and a small amount of the greasewood appear. The soil has an average depth of perhaps two feet, and in places is underlaid with a silicate hardpan in its more level parts. It apparently has a good supply of plant food and is a little inclined to be alkaline in its flattest portions. The area selected is believed to have fairly good drainage and to be suitable for irrigation purposes.

Medium Sand. —Medium sand occupies the higher slopes near the upper margin of the project along the Conley Hills and along the hills surrounding the Fort Rock Unit. The soil has been formed partly by gravity but largely by wind action, and frequently there are several feet of loose material before any hard formation is encountered. The average depth would be perhaps three feet, the depth ranging from three to six feet. In some places the slope is greater than would be most desirable for irrigation purposes. The soil is a little inclined to blow, but irrigation will be necessary to the profitable improvement of this soil and would help overcome drifting. The area of this type within the proposed boundary of the project is limited. It constitutes but 8.5 per cent of the project.

Dark Fine Sandy Loam. —Dark fine sandy loam soil is encountered surrounding Paulina Marsh and appearing in islands in the marsh which are of a more sandy texture than the land that is habitually affected by water. This land has been much affected by water and contains a considerable amount of silt and is dark brown in color. The native vegetation is largely yellow sage. The land is visibly alkaline in places. A small amount of this type of soil is included within the project. This is located where it is believed that the alkali can be washed out and carried away by the natural drainage channels in the land. This soil has good depth and in places where it has been irrigated considerably the hard pan has been dissolved out. Where this is not the case, the hard pan is encountered at about two feet. This soil, apparently, has a good supply of plant food and is well adapted to the root crops and grasses which can be raised at this altitude. Sweet clover is a promising plant to help improve this soil where alkaline.

Black Silt Loam. —The soil that is found near the open water and which is covered with water at certain times is black

Digitized by Google

in color and contains more silt and clay. It is a str
though to some extent a little heavier in texture tha
be ideal for irrigation purposes at this altitude. It co
the best native meadow land in the region and is usual
feet or more in depth and is a little too flat-lying to
for irrigation purposes. It is adapted to the grasses a
crops which will grow at this altitude. These natural m
can be greatly improved by seeding in timothy and alsik

The soil in a considerable part of the lake bed o
Lake is fine sandy loam of very good texture and appar
good fertility. It appears to be a soil that would be wel
to irrigation and to cultivation to crops that can be gr
this altitude.

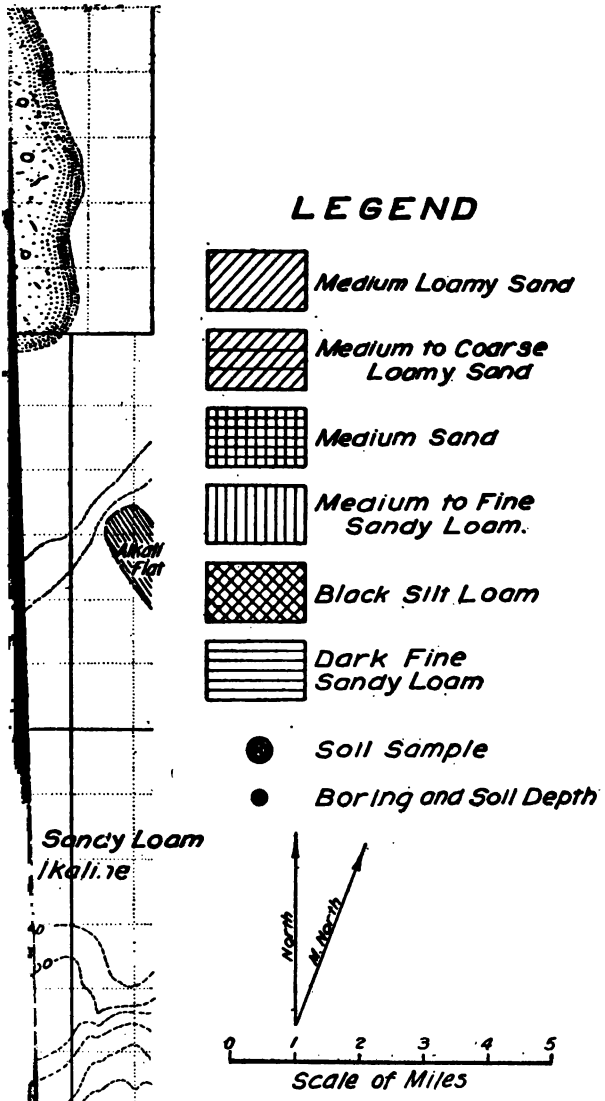
The soil in the flat east of the Fort Rock Unit o
land that is too flat to afford suitable slope for irriga
drainage and it contains a very appreciable amount of
which is accumulated on the surface and forms a cru
places the texture of the soil has a heavier tendency an
the presence of alkali is indicated by the vegetation wi
salt grass and greasewood. This type of soil has not be
lected for it has been regarded as less suitable than othe
that were available for irrigation in this district. On th
at the north side of the flat, southeast of Fort Rock nor
east of the Loma Vista schoolhouse is a body of land wit
slope and topography which is well suited to irrigation pu
and can be successfully irrigated provided it is feasible fr
engineering standpoint.

A general soil map of the area accompanies this r
See Sheet No. 21. This shows roughly the location of th
areas described. It also shows the depth of representative
ings and the locations from which soil samples were coll
for analysis.

Soil Fertility and Alkali.—Where a favorable soil moist
content has been maintained, the soils of this project h
produced good crops of hardy grain, forage and root crops
are best suited to the climatic conditions. The land include
the project has been selected with due consideration to na
vegetation and judgment of farmers having some experienc
the locality, and is regarded as soil of average productiven
The nitrogen supply in an arid soil can be increased more rea
with aid of irrigation.

Samples of medium loamy sand were submitted to the S
tion Chemists for analyses. The determinations made by
Beard follow:

Digitized by Google



SOILS CLASSIFICATION

OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon

Project	SILVER LAKE
Feature	Soils Classification
Designed or Surveyed by	Powers — Date 1915
Drawn by	
Traced by	Rullman — 6-15
Checked by	Powers
Scale	0 1 Miles 2 — Project File No. 21

Digitized by Google

Digitized by Google

Chemical Analyses of Medium Loamy Sand.

	Total Nitrogen %	Total Phosphorus. (P_2O_5) %	Total Potash %	Total Alkali Salts %
Sample No. 2: Surface Soil: (Raw land 1 mi. S.E. of town of Silver Lake)	0.10	0.17	1.42	0.022
Sample No. 5: Surface Soil: (Cultivated land ¼ mi. E. of town of Fort Rock)	0.117	0.217	1.77	0.038

Comments upon these analyses by the Station Chemist, Professor H. V. Tartar, were made as follows:

"Both these soils seem to have a very good content of potash. The phosphorus also is present in goodly amounts, the quantity in Sample No. 2 being about average. The content of nitrogen, like many soils from Eastern Oregon localities, is not high, being about half as much as we find in our Western Oregon soils. However, the nitrogen in the soils of this eastern region is apparently very available and we have found many productive soils that do not contain more nitrogen than these samples.

The quantity of alkali salt present is small, not being large enough, in my judgment, to be detrimental to the growth of crops."

The areas included in the project are those that show least indication of developing alkali trouble with several years of irrigation. The sample analyzed from near Fort Rock comes from a place with less slope per mile than obtains where the sample from near Silver Lake was collected. This probably accounts for the somewhat larger amounts of different soluble materials. The analyses indicate considerable uniformity in the relative supply of plant foods.

Alkali may give a little trouble at the lowest elevation of the project in a few limited areas but most of the project proposed appears to have drainage enough to insure protection against serious alkali trouble. Land bearing much yellow sage or greasewood or salt grass has been mostly excluded from the project. There is a small amount of yellow sage land included in the area north and east of Silver Lake near the edge of the marsh that is visibly alkaline. It is so situated that the alkali could be partly flushed off and the hardpan dissolved by fall irrigation and surface drainage.

Irrigation.—A rather crude system of wild flooding has been practiced on the natural meadows for perhaps twenty years or longer. A small amount of land so irrigated occupies some of the lower sections in the proposed project adjoining the Paulina Marsh. These natural meadows could be greatly improved if the water were controlled and applied throughout the growing season as needed to provide a favorable moisture content in the soil. The heavy irrigation now received in the spring ex-

Digitized by Google

cludes the air from the soil, makes the soil cold and causes the soil structure to be broken down. The cementing material in the soil becomes dissolved and the soil runs together and becomes water-logged. This condition is not best for the weathering of plant food or bacterial activity or growth of plants. Even a more thorough system of contour flooding would be a great improvement on these lands but the gentle slope surrounding the marsh could be better irrigated by the border method of flooding.

The medium loamy sand has not been irrigated much in this district. Mr. J. L. Thompson living near the Loma Vista school east of Fort Rock has irrigated his garden for at least three years and has found that the soil works very nicely under irrigation. The water has been applied here by the furrow method. It is believed that for general grain, hay and stock farming for the next ten years the border method of flooding will be suitable for the gently sloping lands within this project, but to bring it into a higher state of production furrow method of irrigation will come more and more into use as the project is developed. The furrow method should be used for all cultivated crops from the beginning.

The depth and texture of the most important soils on the project is such as will require only moderate amounts of irrigation to regulate their moisture content properly in this climate. Row stuff and grain will probably not require more than one irrigation, as the spring rains will usually bring these plants to the blooming point. On these crops perhaps one-half acre foot per acre on the land would be a reasonable allowance of water except on the limited areas of the coarser textured soils. Clover and timothy would require perhaps two or three irrigations of four or five inches deep. A reasonable allowance for such crops would be twelve to eighteen inches depth per acre.

Since the soils are to a large extent naturally mulched, due to their loose texture on the surface and because they are rather loamy underneath, they should retain moisture well. Considering also that there is a greater land area available for irrigation than can be supplied by the water resources of this region, it would seem that a reasonable allowance under these conditions would be one acre foot of water per acre delivered to the forty.

Drainage.—The land selected for the proposed project occupies a slope or low terraces leading to the flat floor of the Paulina and Fort Rock basins and generally has fairly good natural drainage. At this altitude, under present conditions, land that would require under-drainage for its reclamation would be too expensive to reclaim. There is a small amount of yellow sagebrush land northeast of Silver Lake that appears to contain injurious quantities of alkali. Located as this land is, close to the source of the supply of water and close to the outlets from

Digitized by Google

Paulina Marsh into Silver Lake, it is believed that this alkali can be flushed out by fall irrigation and carried away in surface drainage channels. This is the only sort of drainage that it is believed would be cheap enough to be warranted under present conditions. While drainage problems are not apt to become serious within the project itself, there are lands located in the Fort Rock Basin, below the proposed project that should be protected from injury by alkali through the economical use of water should the project be irrigated.

Probable Value of Irrigation and its Effect upon the Agricultural Practices of the District.—An important advantage of irrigation in this district would be that it would provide a more favorable moisture content to help force crops during the short growing season that obtains. Irrigation would also make it possible to secure a more dense settlement and to provide more windbreaks of very hardy trees or shrubs which would lessen the wind sweep in the district and help control the drifting of the soil. Irrigation water applied to a soil generally tends to consolidate it and to aid in building up the humus content so that there is less tendency for a soil to blow when it is irrigated and a large part of the surface is seeded down to meadow crops. With the short growing season, only moderate yields per acre can be expected. It is believed that clover and timothy would yield one and one-half to two tons per acre with irrigation. It is very probable that alfalfa would succeed on the deeper soils in the district where there is some air drainage to relieve the plants from the extreme frost. Grain hay with irrigation should yield from one to two tons per acre, whereas the yield now is one-half or three-quarters of a ton per acre. Irrigation would make it possible to raise one crop each year on the land whereas about half of the land area is devoted to fallow under the present dry-farming system of cultivation. It would make it possible to raise legumes to build up the nitrogen content of the soil which appears to be its weak point. It would make it possible to build up the water capacity of the soil and the humus content and the supply of available plant food. Irrigation would make it possible to keep more livestock and to practice a more diversified, intensive and permanent system of farming in the district.

The fact that the land holdings are generally half section homesteads which have been obtained at nominal cost would tend to prevent land speculations on this project, and permit the settlers to realize the full benefit of irrigation. At the estimated cost of twenty-five to thirty dollars for water right of one acre foot per acre and delivered to the land it would be a benefit to the settlers to have irrigation water provided. The irrigation would cost about all it is worth under present conditions.

Digitized by Google

at this price, but it is necessary to the highest development of the land affected. With improvement of transportation facilities the project should become readily feasible within a few years; in fact, it is believed that the Silver Lake Unit of this project offers a comparatively good field for investment of either public or private capital, and its development appears feasible now.

LAND OWNERSHIP

Stock raising, including the development of wild hay lands, is one of the land industries in which large land ownership may be made most profitable. In the range countries, therefore, it is usually found that the bottoms or hay lands are controlled often by single corporations, or at most by a few owners. Paulina Marsh, which is wild hay land, is found, therefore, largely controlled by some three or four owners, probably operating as one company.

The lands of Silver Lake Unit and Paulina Unit are, with few exceptions, held by owners in tracts of 320 acres or less. The Fort Rock and Horning Bend Units, falling within the enlarged homestead area, are also largely held in homesteads of 320 acres or less, patented and unpatented. The status of the lands under these several units is shown on Sheet No. 42, the ownership of all tracts in excess of 320 acres being shown with a number referring to the name of the owner, indicated on the margin of the sheet.

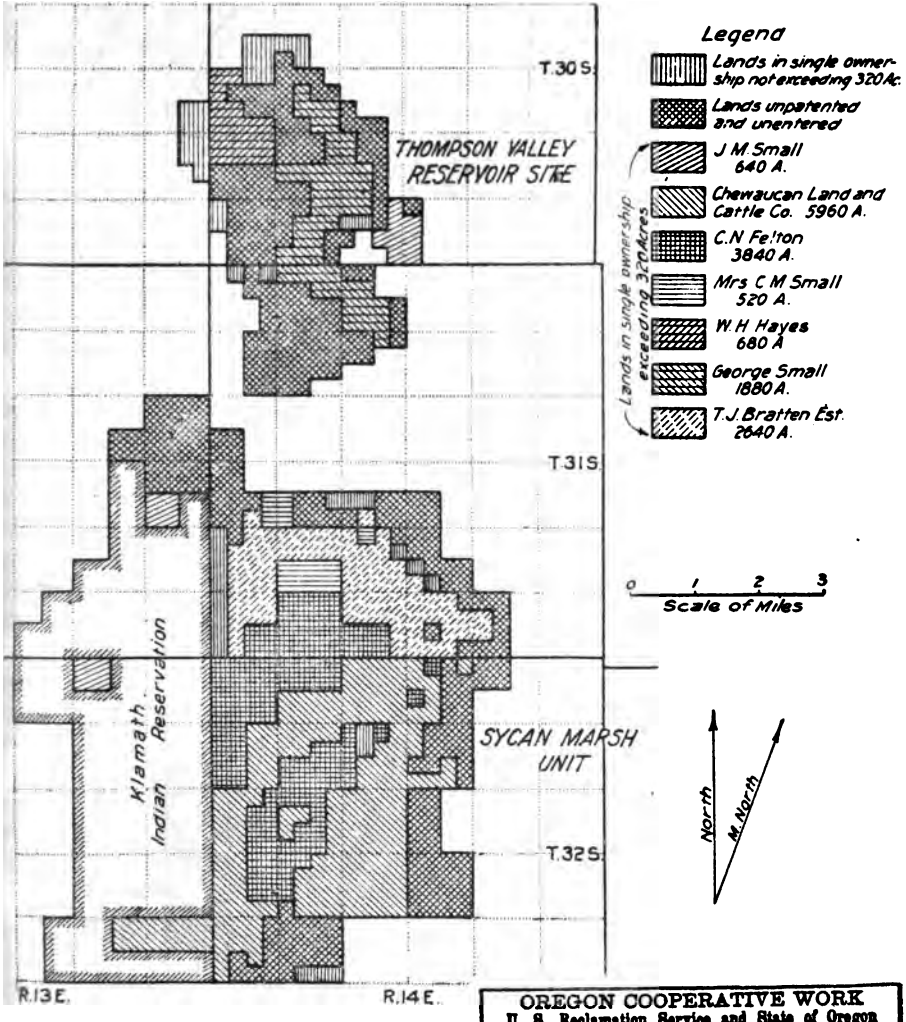
The land ownership in Thompson Valley and Sycan Marsh is shown on Sheet No. 41. A large part of the Thompson Valley reservoir site appears to be unpatented, and the area patented is held principally by two individuals.

Sycan Marsh, outside of the Klamath Indian Reservation, is controlled almost entirely by three owners, the Chewaucan Land and Cattle Company, C. N. Felton and the T. J. Bratten Estate.

The ownership of the bed of Silver Lake, which is discussed as a possible future development, is not shown, but since the lake occasionally goes dry and is at other times comparatively shallow, it is assumed that it is not, within the meaning of the Federal Constitution, a navigable body of water and therefore that the lands reclaimed would belong to the State. While this would be an important question for adjustment in case of such irrigation development, it is not one which materially affects the conclusions of this report, and it has not therefore been regarded as essential to have a legal discussion of that phase of the question prepared.

Digitized by Google

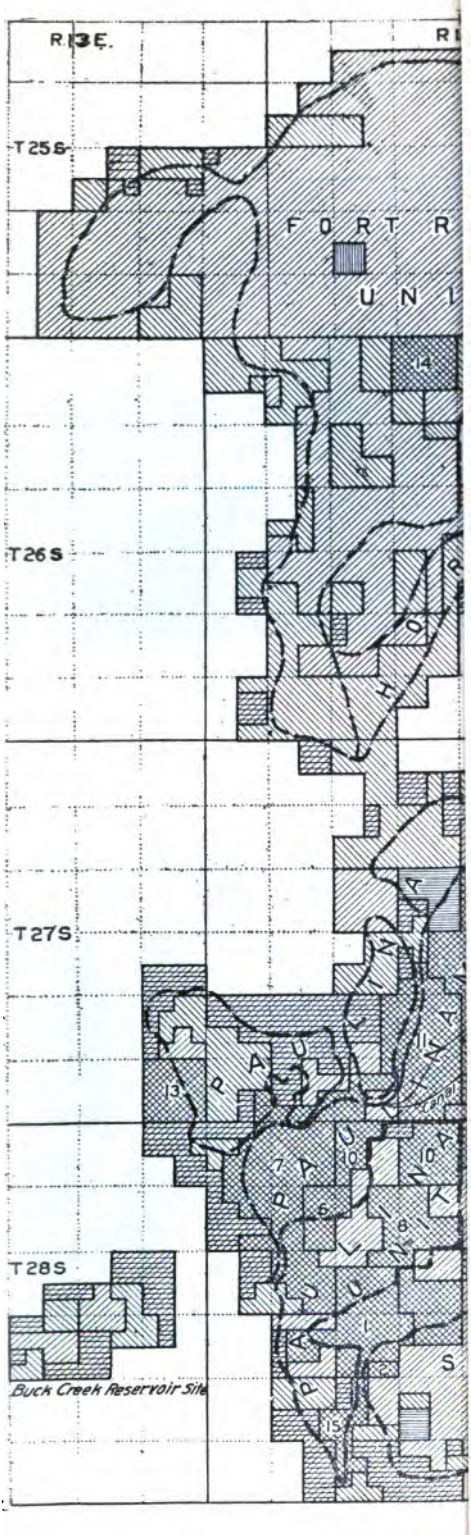
LAND OWNERSHIP
THOMPSON VALLEY AND SYCAN MARSH



OREGON COOPERATIVE WORK U. S. Reclamation Service and State of Oregon		
Project	SILVER LAKE	
Feature	Land Ownership - Thompson Valley Res. Site and Sycan Marsh Unit	Date
Designed or Surveyed by		
Drawn by	MEARA	9-1915
Traced by	Rullman	"
Checked by	Meara	"
Scale	1 Mile = 1	Project File No. 41

Digitized by Google

Digitized by Google



Digitized by Google

Digitized by Google

GRUBBING SAGE BRUSH IN FORT ROCK VALLEY PLATE 5

ENGINE USING SAGE BRUSH FOR FUEL PLATE 6
PLOWING CLEARED LAND—FORT ROCK VALLEY

Digitized by Google

Digitized by Google

GENERAL DISCUSSION OF PROBLEMS AND PROJECT PROPOSED.

In the development of a plan for any project contemplating the use of waters from a number of streams of which the summer flow has been in part or wholly appropriated, there are a great many problems entering which are not easy to anticipate. In the first place, those who have been the pioneers in the country and in the use of water for irrigation have established rights which may have been adjudicated in part but in general are not well defined. Even when adjudicated in the manner in which rights are set forth by decrees of the court having jurisdiction in these matters, as so many inches of water per acre of land, the question of when this use is to begin in the early spring is not fixed. This is an important question in determining what amount of water from the early flow of the stream may be counted on for storage to provide water for use on new lands. The adjudicated right gives a water user the right to a certain amount of constant flow at any time that he may desire to use it. This leaves the question open as to when storage, after the irrigation season ends, may be begun for the next year's supply.

Water rights on Silver Creek have been adjudicated to the extent of about 50 second feet. By reference to the hydrograph of Silver Creek for a mean year, presented on Sheet No. 36, it will be seen that if the entire flow of Silver Creek from about September 1st to April 1st could be stored, as well as that part of the flow during the remaining months of the year which exceeds 50 second feet, the supply available for storage for use on new land would be about double that available if only the amount in excess of 50 second feet could be counted on, as would be the case if the water users insisted on the full 50 second foot flow throughout the year to which they might legally be entitled.

An investigation of this kind does not generally permit of the collection of facts and data for presenting an equitable adjustment of the problems which will of necessity come up in case the project is undertaken. All that can be done is to present the main problems and consider them in relation to their effect upon the project proposed.

EXISTING WATER RIGHTS AND PROBABLE SUPPLY AVAILABLE FOR OTHER LANDS.

Although Paulina Marsh was settled in the early "Seventies" no attempt was made to divert water from the streams entering the marsh until several years later. The first diversion of Silver Creek was made about 1875. From that time on, waters began to be appropriated rapidly until in 1895 practically all of the summer flow was taken up. In years of low run-off the later appropriators had difficulty in getting all the water they re-

Digitized by Google

quired. This led to difficulties between the users. The final outcome of these difficulties was an adjudication of rights on Silver Creek by the Courts.

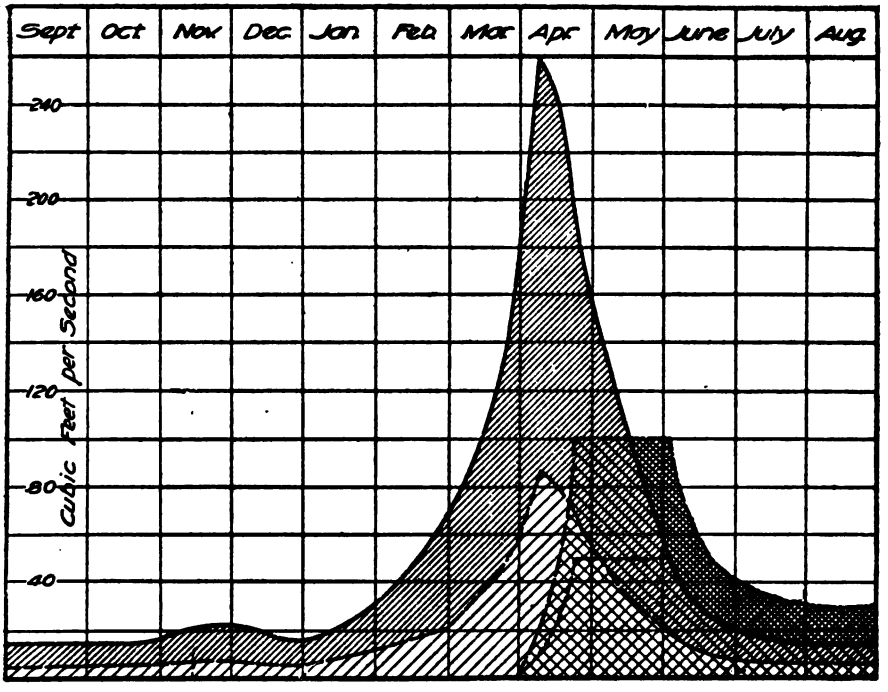
Silver Creek.—The rights on Silver Creek were adjudicated in 1909 in the case of Hough vs. Porter. This adjudication was made prior to the law now in effect whereby the State Water Board makes the adjudications with the decree of court confirming or modifying the same. This case of Hough vs. Porter is recorded in Volume 51, Decisions of the Supreme Court of Oregon. The opinion was prepared by Judge Will R. King.

In this adjudication there were a few late appropriators whose rights though not determined were explicitly stated in the opinion as not to be lessened by their withdrawal from the proceedings. Following is a tabulation of rights adjudicated in this decision, omitting No. 12, which was a right for water to be applied on land located in the Thompson Valley reservoir site. These lands to which rights have been adjudicated lie immediately to the north of the Silver Lake Unit of the proposed project, as shown on Sheet No. 34, except 240 acres located mostly in the Egli reservoir site.

Adjudicated Water Rights—Silver Creek.
Case—Hough vs. Porter.

Order of Priority	Year.	Owner.	Adjudicated Right.		Acres of Land.	
			Inches.	Second feet.	Right applied to.	Owned.
1	1878	Anna C. Hough	100	2.5	200	320
1a	1878	John C. Porter	100	2.5	240	320
2	1882	Lucinda Egli	120	3.0	240	320
3	1880	Marion Conley	100	2.5	240	320
4	1882	George H. Small	40	1.0	60	160
5	1883	S. A. D. Porter	100	2.5	240	320
6	1884	George H. Small	100	2.5	300	1280
7	1885	W.C.Buick and Corina Buick	90	2.25	140	320
.....	.....	Ida M. Corum and others	90	2.25	140	480
.....	.....	J. M. Small	120	3.00	140	680
8	1885	P. J. Chrisman and J. C. Porter	200	5.00	300	360
9	1886	C. C. Jackson	80	2.00	160	160
10	1887	W. H. McCall	80	2.00	160	160
11	1887	B. F. and Jennie Lane	90	2.25	160	320
12	.....	George Durrand	.....	.....	.....	.....
13	1889	Occidental Land & Imp. Co.	80	2.00	120	240
14	1890	E. D. Lutz	100	2.50	200	240
15	1891	F. M. Chrisman	60	1.50	100	160
16	1893	Mary C. Brown	50	1.25	100	320
17	1894	Mary J. Kittridge	160	4.00	480	640
18	1894	P. W. Jones	80	2.00	160	324
19	1896	C. E. McKune	50	1.25	100	160
		Totals	1990	49.75	3980	7604

Digitized by Google



Legend

- Mean flow of Silver Creek 1905 to 1914
- Mean flow of Lower Silver Creek 1905 to 1914
- Probable use by 4000 Acres adjudicated rights
- Probable use by 8000 Acres Hay Lands
- Storage required for 8000 Acres
- Flow available for 8000 Acres from Upper Silver Creek without storage
- Flow available for 8000 Acres from Lower Silver Creek without storage
- Not available for storage at Thompson Valley nor needed for uses here shown
- Available for storage at Thompson Valley

Study of Supply available for Storage at Thompson Valley

OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon

Project	SILVER LAKE
Feature	Silver Creek Water Supply
Designed or Surveyed by	Parkhill — Date 7-16
Drawn by	" — "
Traced by	Henderson — "
Checked by	Parkhill — "
Scale	— Project File No. 36

Digitized by Google

Digitized by Google

It will be noted that in this decision the mean use allowed, measured at the diversion, is one second foot to 80 acres. These rights applied to about 4,000 acres of land and the acreage owned is about 8,000. In most cases the owners have constructed their distributing ditches so that the water which is adjudicated to part of their lands may be used on the remainder if so desired. It will thus be seen that in considering any project using the waters of Silver Creek, the 4,000 acres for which rights were not adjudicated are so related in location and ownership to the 4,000 acres of adjudicated water rights that it will be advisable to consider the 8,000 acres as a whole. The total of 7,604 acres will be considered 8,000 acres, to provide for some other lands which might set up claim of rights on Silver Creek prior to those of any new lands.

The present practice seems to indicate a use of the waters of Silver Creek beginning early in April, reaching the maximum provided for in the various ditches some time in the latter part of April and continuing this use so long as water is available.

Hydrograph of the flow of Silver Creek, Sheet No. 36, has been prepared, showing the discharge in the mean year, also the probable discharge for that portion of Silver Creek below Thompson Valley on which no storage is planned. Assuming that the use on the hay lands in Paulina Marsh begins early in April and increases to the maximum allowed by the adjudication rate in that month, and that water will not be required after September first, the use required for 8,000 acres is shown on this hydrograph for the purpose of illustrating what storage will be required for the 8,000 acres and the supply which will be available for storage in Thompson Valley.

It will be noted that before the use begins in April, there will be a certain amount of waste from that portion of Silver Creek below Thompson Valley, as indicated on the hydrograph. If it is contended by the present users that they desire the water earlier than shown by the use curve this water will be available from the lower Silver Creek, shown as not available for storage, without materially affecting the quantity available for storage at Thompson Valley.

In fact the use of this water on lower Silver Creek in March and early April will be desirable in considering the reclamation of the bed of Silver Lake, which will be taken up later in this report. The hydrograph above represents mean conditions as to the amount of water and the time at which high run-off may be expected. In some years undoubtedly the available supply is much less and the time of high run-off may come early in the spring, in which case the amount of storage required for the 8,000 acres would be considerably more.

Digitized by Google

As a basis for determining requirements for the 8,000 acres for which partial rights have been secured, it is estimated that without storage, Silver Creek in mean years such as 1906 and 1911, will furnish an adequate supply for the 4,000 acres to which rights have been adjudicated.

The following tabulation has been made, showing the diversion duty in acre feet per acre by months and the total acre feet required for the 8,000 acres:

Probable Requirements at Diversion for 8,000 acres Paulina Marsh Lands.

Month.	Acre Feet, per Acre.	Acre Feet required by 4,000 acres.	Acre Feet required by 8,000 acres.
April	.373	1,490	2,980
May	.77	3,075	6,150
June	.475	1,900	3,800
July	.277	1,110	2,220
August	.230	925	1,850
Totals	2.125	8,500	17,000

A study of the hydrograph indicates that there is no water available from the summer flow of Silver Creek in excess of the needs of the 4,000 acres under adjudicated rights, and that to supply the entire 8,000 acres similarly to the lands having these rights, will require approximately 4,000 acre feet storage beginning about May 20th in a mean year.

The annual run-off of Silver Creek has been shown to be about 40,000 acre feet and the requirements for this 8,000 acres of land about 17,000 acre feet, leaving 23,000 acre feet available for storage. This water, after seepage and evaporation losses were deducted, would supply new lands, provided a storage site sufficiently large for this quantity could be found on lower Silver Creek. No such site is available. The Thompson Valley storage site, however, is adequate for several times the amount of water which comes from it each year.

The total drainage area of Silver Creek is 180 square miles, while that of upper Silver Creek at Thompson Valley is about 105 square miles, or 60 per cent of the total drainage area. This is the higher and more timbered portion of the drainage area, and for purposes of this estimate the run-off from Thompson Valley will be considered as two-thirds the total run-off of Silver Creek. With this assumption there will be available for storage in Thompson Valley from September 1st to March 31st, 10,440 acre feet. In addition, from April 1st to May 20th, there will be available, above the requirements for the 8,000 acres heretofore referred to, about 8,670 acre feet, or a total of 19,100 acre feet in a mean year.

Digitized by Google

After allowing 15 per cent for seepage losses in the reservoir, amounting to 2,800 acre feet, and three feet in evaporation losses over the mean surfaces of the reservoir annually, amounting to 3,300 acre feet, there will be left available for irrigation 13,000 acre feet. Deducting 4,000 acre feet to supply the storage requirements of the 8,000 acres of land already having partial rights, there will remain about 9,000 acre feet available at diversion for use on new lands. If no storage is provided on lower Silver Creek there will waste each year about 8,000 acre feet.

Buck Creek.—The waters of Buck Creek are at present used in the west and northwestern parts of Paulina Marsh. The flood waters in the spring are allowed to spread over the marshes which furnish feed for stock. After the stream has reached its more normal flow, temporary dams are used to divert the water over the marsh lands.

Water rights on this stream have not been adjudicated. The mean annual discharge of Buck Creek is about 15,000 acre feet, and it is believed there may be 5,000 acre feet of water available for new lands from Buck Creek with storage. The lands in the northern end of Paulina Marsh to which the Buck Creek waters have found their way have become the most alkaline in character of any lands in the Paulina Marsh. In time these lands will need drainage. When this is provided the lands in Paulina Marsh which can best be supplied from Buck Creek will require all the supply available from that source, even under storage development.

Bridge Creek.—The waters of Bridge Creek come into use about as early as those of Silver Creek, which it joins a few miles north of Silver Lake. At the time the adjudication was made of Silver Creek waters, rights to the flow of Bridge Creek were granted for about 300 or 400 acres of land. These rights are considered to require practically the entire summer flow. The annual discharge of Bridge Creek is about 5,000 acre feet, of which it is estimated about 3,000 acre feet will be available for storage in the fall and winter months. This will provide, after seepage and evaporation losses are deducted, about 2,000 acre feet for use on new lands.

Sycan Marsh Tributaries.—No rights to the waters of the streams entering Sycan Marsh have been adjudicated. There is great uncertainty as to the inflow of these streams and also as to the amount which may be diverted from them to be used on other land. Sycan Marsh with its bordering grassy slopes is used as a summer range for several thousand head of cattle. There are about 14,000 acres of land in the low part of the basin which may be considered the marsh proper, and about 8,000

Digitized by Google

acres of land bordering this marsh which have a light slope upward to the foot-hills. The marsh is covered with tall marsh grass, tules and some willow, while the bordering lands are covered with short grass. The streams which enter the marsh from the surrounding mountain slopes have their greatest discharge in April and May, when the marsh becomes more like a lake. In the latter part of the summer the water recedes and the cattle range over the greater part of the marsh.

The waters of Long and Coyote creeke, entering the marsh from Klamath Indian Reservation on the west, are diverted over the bordering slopes in the late summer when these sloping lands have become dry. The extent to which these diversions have been made is very uncertain.

A diversion has been made from Sycan River at about the center of Section 21 in Township 32 South, Range 14 East, near the "ZX" ranch house. The diversion works at this point are estimated to be capable of diverting about 40 second feet. The water is used to irrigate slopes lying to the north of Sycan River.

The following estimate has been made of inflow into Sycan Marsh in a mean year. See "Water Resources, Sycan Marsh Drainage."

Mean Yearly Inflow from Sycan, Chocktoot,

Long and Coyote Creeks	121,700	ac. ft.
Additional inflow from 80 square miles other tributary area	30,300	" "
Total mean yearly inflow	152,000	" "

No records of flow from the outlet of Sycan Marsh have been made, but during the spring and summer of 1914 measurements were made of the discharge of Sycan River near Yainax, Oregon; also of Sprague River near the same place and above the junction of Sycan River with it. From a study of these records the following estimate has been made of the outflow from Sycan Marsh. Column 2 is the measured and partly estimated (e) flow of the Sycan at Yainax, column 3 the estimated discharge of the 208 square miles of area tributary to Sycan River below Sycan Marsh, and column 4 the difference between columns 2 and 3, or the probable outflow from Sycan Marsh.

Digitized by Google

Estimated Outflow from Sycan Marsh March to July, 1914.

Month.	Sprague R. near Yainax.	Sycan R. near Yainax.	Sycan R. below Sycan Marsh, estimated.	Outflow Sycan Marsh, estimated.
	513 sq. mi.	508 sq. mi.	208 sq. mi.	300 sq. mi.
March	38,600	e 41,000	15,500	25,500
April	40,300	40,000	16,300	23,700
May	26,400	21,800	10,500	11,300
June	14,000	8,980	5,500	3,480
July	9,160	4,810	3,490	1,320
Total	128,460	116,590	51,290	65,300

While the above tabulation includes only five months, it is believed the outflow from Sycan Marsh before and after this period was, if anything, very small, as indicated by records of flow on Sprague River below the junction with Sycan River. From the fact that the year 1913-14 is slightly below the normal year for streams in this part of the state, the mean yearly outflow from Sycan Marsh is thought to be about 70,000 acre feet. It would thus appear that the diversion of about 70,000 acre feet from the streams entering Sycan Marsh will not materially affect the present use of water on the marsh or bordering lands.

It will be shown under "Proposed Project—Water Supply" that with the assumptions made as to capacity of canals diverting from streams entering Sycan Marsh and the time of this diversion, the mean yearly delivery to Thompson Valley reservoir will be 64,000 acre feet. Taking into consideration the canal losses which would not return to the marsh from the canals, there will be required a diversion from Sycan River of not to exceed 70,000 acre feet. After June 15, when no more diversion to Thompson Valley is planned, these canals will be of great value in distributing water to the bordering slopes of the marsh, and thus be an actual benefit to those lands.

With the estimated mean yearly inflow of 152,000 acre feet to Sycan Marsh and the proposed diversion of 70,000 acre feet to Thompson Valley, there will remain 82,000 acre feet, which is nearly four acre feet per acre on the 22,000 acres of marsh and bordering slopes.

It is believed that 1.5 acre feet of water would be ample for these rich, peaty marsh lands of great water holding capacity, and that 2 acre feet as allowed for the border grass lands would be a liberal allowance. In view of the fact, however, that excessive claims to water for similar lands have been made in the past and that the attitude of the courts in dealing with such marsh lands is not as yet well settled, it seems advisable in this case to make liberal provision for these lands, leaving until the future any planning to utilize the surplus which may remain

Digitized by Google

when water rights of this basin have been adjudicated by proper authorities. The courts tend to insist more and more that those claiming beneficial use of waters be required to provide reasonable irrigation as well as drainage systems. It therefore seems fair to assume that the four acre feet above mentioned will not ultimately be allowed.

The diversion of 70,000 acre feet from streams entering Sycan Marsh will undoubtedly diminish losses due to evaporation from its surface. Consequently the resulting losses to lower Sycan River will be less than 70,000 acre feet. Whatever these losses may prove to be, they must be taken as directly affecting the development of power and irrigation on lower Sycan River. Whether this water could be used to greater advantage on the lower Sycan or on bottom lands along Sprague River than for the proposed Silver Lake Project is a matter which cannot be discussed here, because of lack of information as to the amount of irrigable lands which could be irrigated from the lower Sycan and as to the cost of such development.

Fred F. Henshaw (See "Early Investigations and Surveys.—U. S. Geological Survey—1912") has considered the development of storage on the lower Sycan, power for pumping to Klamath Marsh lands, and irrigation of about 25,000 acres along the lower Sycan and Sprague Rivers near Yainax.

A reference to discharge records of Sycan River at Yainax and above Sycan Marsh indicates that comparatively little of Sycan Marsh water runs off into the lower river. Whether or not water requirements for Klamath Indian Reservation below Sycan Marsh would interfere with the proposed diversions, or whether the diversion of Long and Coyote Creeks within the Reservation would be opposed, has not been ascertained.

No special investigation has been made by Oregon Co-operative Work of the possible use on Reservation lands of the waters flowing into Sycan Marsh which it is proposed to divert, for the reason that such investigations are now being made by the Indian Service, the report on which will probably be made public.

A legal question is involved as to the right which the State, or the Federal Government, may have to divert waters of Sycan River above the Indian Reservation. The question as between claimants by so-called riparian right and those claiming under prior appropriation and use has not been determined by the United States Supreme Court. Moreover, there are treaty rights under which the Indians may claim, and if the doctrine of riparian right is upheld by the Supreme Court of the United States, any diversion proposed from tributaries of Sycan Marsh may be absolutely prevented by the Indians. In this connection

Digitized by Google

it should be noted that there are already diversions from these streams above Sycan Marsh, the rights to which have not been disputed by the Indians.

It is not believed that in the proposed diversions there can be any interference with the Klamath Project now under construction by the Reclamation Service because for any possible future extension of that project there can hardly be any shortage of water during the period in which Silver Lake Project diversions are proposed.

Reliability of Estimates.—The estimates of supply available for other lands, from the streams considered, cannot be regarded as being very reliable with the exception of that for Silver Creek. For this stream the records of flow have been fairly complete since 1905, and the adjudicated rights and well known practices in using the waters of Silver Creek at the present time furnish favorable conditions for making an estimate. No records have been kept of the flow of Silver Creek at Thompson Valley. Consequently the assumption that two-thirds of the Silver Creek run-off comes through the valley is not based on actual information. However, it is believed that this estimate of the flow of Silver Creek at Thompson Valley is conservative, since the area drained through it is 0.6 of the whole area drained by Silver Creek, is a heavily timbered area and is at a higher elevation than that of lower Silver Creek, which is timbered only in part. The estimates of supply available from Buck Creek and Bridge Creek do not have any bearing on the proposed project as outlined later in this report, since the use of their waters is not included.

Under "Water Resources" it was shown that the inflow into Sycan Marsh was actually measured only in the one season of 1905. By comparisons of the discharge during this one season, of Sycan River above the marsh with that of Silver Creek and Chewaucan River during the same period, ratios were established for estimating the discharge of Sycan River during the later years when records were not kept. See Sheet No. 40. While the results so obtained are the best that can be estimated from available information, they are not in any sense to be considered as entirely reliable. However, should they be found, after keeping actual records over a period of years, to be as much as 25 per cent in error, it is not thought the proposed project, as outlined later, would be seriously affected as to cost of construction per acre. If the run-off proved to be less than herein estimated, the project would have to be cut down in respect to the amount of land irrigated, and there would be a corresponding decrease in storage capacity required, height of storage dam, size of main feed canals, etc.

Digitized by Google

DUTY OF WATER AND IRRIGATING SEASON.

Duty of water is an expression used in connection with irrigation to show the depth of water used in a season. The duty required in different localities will vary with the climate, rainfall, nature of the soil and length of growing season. It will also vary from month to month. A common expression for this duty is in acre-inches per month. An acre-inch is the quantity of water which will cover one acre of level land to a depth of one inch, and the acre foot is twelve times this amount. Duty of water for a season is ordinarily expressed in acre feet, as the duty required is usually an acre foot or more up to even five or six acre feet for gravelly, porous land.

The oldest expression common in this country for duty of water is the miner's inch, which came into use in the western states in connection with hydraulic or placer mining. It developed from the necessity for a simple method of measurement, this same unit of measure was subsequently used for expressing flow of water for irrigation uses.

Litigation over rights to streams used for mining purposes led to definitions of the miner's inch varying in different states from one-thirty-eighth to one-fiftieth of a cubic foot per second. In this State the Courts have ruled that 40 miner's inches is equivalent to a flow of one cubic foot per second. See table of adjudicated water rights on Silver Creek under "Existing Water Rights," etc.

In the early days of irrigation when no storage was provided it was convenient to express the amount of water used as so many miner's inches or so many second feet (an abbreviation for cubic feet per second) during a given period of time.

Nearly all projects of the present day require storage for a part or all of the water to be used in irrigation. The amount of water stored is considered in terms of volume, and consequently it has become general practice to express the duty of water used in irrigating as a volume of water such as the acre inch or the acre foot. The acre foot will generally be used throughout this discussion.

The irrigating season is the time during which irrigating is carried on and varies with the climate and nature of crops grown. The season usually begins shortly after seeding time, to assist in the germination of the seed, and continues throughout the summer, the last irrigation being usually for pasture. Generally speaking, there will be some month in summer when the amount required will be gerater than for any other month.

The capacity of main feed canal for any proposed project will be determined by the duty required for this high month. From this very fact, due to the relation between capacity and

Digitized by Google

construction cost, it is evident that it is to the interest of water users to limit themselves during such high month to the lowest amount consistent with actual needs.

The duty of water and the irrigating season for the project proposed have been decided upon after consideration of the following matters having a bearing on the subject.

Present Use on Wild Hay Lands.—The present use on the wild hay lands of Paulina Marsh cannot be well stated in terms of acre feet per acre, but will be briefly outlined as follows:

Generally speaking each farm has its own ditch diverting water directly from Silver Creek or Bridge Creek as the case may be. Irrigating is begun in April and continued to the full capacity of the ditch until just before time for cutting hay. In years of low run-off those having the first adjudicated rights generally get sufficient water for their hay crops, but those having the later rights, while they may get sufficient water during the early part of the season, do not obtain the required amount in the later months. It is understood that in years of mean run-off such as 1906 and 1911, there was an adequate supply for the 4,000 acres to which rights have been adjudicated.

Under these conditions of use, as outlined on the hydrograph heretofore referred to, the use by months has been estimated and is shown in the first column in the tabulation under "Existing Water Rights." It totals 2.125 acre feet per acre at diversion. With an estimated loss of about 20 per cent in the farmers' ditches, this would equal about 1.7 feet per acre delivered to the land.

Investigations in Idaho—Bark.—Some very interesting and comprehensive investigations on duty of water were carried out in the Snake River Valley in Idaho in the seasons of 1910 to 1913 inclusive by Don H. Bark.* The investigation covered a wide scope of territory, and the experimental tracts included all types of soil from the finest adobe clays to coarse gravel. Elevations ranged from 2,100 to 4,950 feet above sea level. The experimental tracts were generally about 15 acres in extent and were accurately measured. The quantity of water delivered to the tracts, as well as waste from them, was carefully noted and recorded.

The conditions as to soil, temperature and rainfall are so similar in Central Oregon to those in much of the territory under investigation by Bark that the results he obtained should have a great deal of weight in determining a duty of water for this project. Tables were prepared, showing the effect of using

*Duty of Water Investigations by Don H. Bark, Irrigation Engineer, in charge of Irrigation Investigations in Idaho. Office of Experiment Station, U. S. Department of Agriculture.

Digitized by Google

different amounts of water on grains, alfalfa and other staple products of Idaho during four seasons. There were 415 plots aggregating 1,842.5 acres. The majority of the experiments were conducted with alfalfa and grains. A summary of the results obtained can best be given by quoting Bark as follows:

"It was found early in the investigation that there was a great variation in the water requirements of the various soils and crops. The soils and crops, however, so far as water requirements are concerned, have seemed to automatically resolve themselves into two classes each, (1) those requiring the least water, and (2) those requiring the most water. The crops belonging to the first class, those requiring the least water, are spring and winter grains, potatoes and clean cultivated orchards. Those belonging to the second class are alfalfa and other hay and pasture grasses. The soils that require the least water are the medium or clay and silt loam soils of a reasonable depth. This class includes adobe, lava ash, clay loam, and fine sandy soils, or any soils of a reasonable depth that is not porous. The soils requiring the most water are the porous soils, such as the coarse, sandy and gravelly soils. For the purpose of illustration, discussion and comparison, the soils and crops will hereafter be tabulated and discussed in this report under the two above-mentioned classes. The average irrigated soil of Idaho, and of most other western states, falls in the medium or first-mentioned class, the percentage of extremely porous irrigated soils being quite low. The tables and discussion in regard to the medium soils will therefore be of more use and interest than those dealing with the porous soils.

The following tables have been compiled from results secured throughout the investigation with the medium or less porous type of soil. This table is made up (1) by showing the average results secured from all of the alfalfa plots included in the investigation that were grown on medium soil, and (2) by selecting the plot which made the maximum yield from each 15-acre experimental tract, irrespective of the amount of water applied, and forming a general average of the results secured from all of them, some 26 in number. The same method of procedure has been followed with the grains.

Average Results Secured on Clay Loam Soils during Four Years, 1910 to 1913, inclusive.

Description of Plots.	Crop.	No. Plots.	Average depth water applied.	Average yield per acre.	Average yield per acre foot of water.
			Feet.	Tons.	Tons.
All plots included in investigation.....	Alfalfa	79	2.40	4.91	2.04
Plots making maximum yield in each experiment irrespective of amount applied.....	Alfalfa	26	2.73	5.47	2.00
				Bu.	Bu.
All plots included in investigation.....	Grain	221	1.33	36.38	27.39
Plots making maximum yield in each experiment irrespective of amount applied.....	Grain	60	1.74	44.92	25.79

It will be interesting to note that the second and fourth lines of the table in which are included all of the maximum yields produced, irrespective of the amounts of water applied, show that the maximum yield required considerably more water than was applied to the average of all plots. This strongly indicated that at least up to a certain point the greater amount of water applied, the greater the yield. The last column of the table gives average yield per acre foot of water applied, which is a thorough index of the efficiency secured from the water. It will be noted that, while the most water produced the most crop, the amount of water required to produce the average maximum yield gave less efficiency with alfalfa than the average amount applied to all plots, and that the water required for the maximum yield of the grains was considerably less effi-

Digitized by Google

cient than the average applied to all plots. Consisting of so many plots, which were observed during so many different years, the above table should be very dependable, and will no doubt be interesting to irrigation companies and others, many of whom have become too enthusiastic during the last few years over the benefits that are obtained from an abnormally high Duty of Water."

Summary of Depths of Water Applied by Months to One Hundred Seventy-one Fields of Grain and Alfalfa on Medium Clay and Sandy Loam Soils.

Altitudes ranging from 2,400 to 5,000 feet. Seasons of 1910, 1911, 1912 and 1913

Season.	No. of plots.	April		May.	June.	July.	Aug.	Sept. 1-15	Total for Season.
		1-15	16-30						
119 Fields of Grain:									
1910	31	.....	.....	.3210	.6000	.5460	.0780	.....	1.5450
1911	30	.....	.....	.0270	.6540	.4780	.0100	.....	1.1690
1912	25	.....	.....	.....	.9420	.6550	.0460	.....	1.6430
1913	33	.....	.0392	.2062	.5434	.5941	.2268	.....	1.6097
Average	.....	.....	.0098	.1385	.6849	.5683	.0902	.....	1.4917
Per cent of total	.....	.....	.66	9.28	45.91	38.10	6.05	.....	100.00
52 Fields of Alfalfa:									
1910	15	.0600	.0210	.5540	.7390	.6530	.6070	.0650	2.6990
1911	13	.....	.0350	.4930	.2930	.9130	.0970	.2480	2.6790
1912	11	.....	.....	.4910	.5030	.6210	.6080	.0380	2.2610
1913	13	.....	.....	.8627	.2284	.7422	.3854	.0175	2.2362
Average	.....	.0150	.0140	.6002	.4408	.7323	.5744	.0921	2.4688
Per cent of total	.....	.61	.57	24.31	17.86	29.66	23.26	3.73	100.00

"The above tables, as has been stated, include only plots that have demonstrated by the yields produced that they were cultivated and irrigated in the best possible manner. The average amount applied during the 4-year period is shown at the bottom of the last column of each table, and is the amount which the author deems the best economic amount for the crop in question when planted on a medium clay loam on average South Idaho soil. The amounts of water tabulated in the above tables are the amounts that have been actually retained upon the fields in question, the waste water having been deducted.

It is believed that the two tables immediately preceding will be found the most valuable and most dependable of any that it is possible to include in this report, for they are a general summary of the four years' investigation in Idaho."

In order to determine the comparative areas commonly under cultivation for the two types of crops, that is hay and pasture requiring the higher duty of water, and grain, potatoes and orchard requiring the lower duty, a census was made of several large projects in Idaho representing a total of about 383,000 acres. The results obtained indicate that about an equal acreage was devoted to each class, the exact percentage as tabulated in the summary of the census being 49.08 per cent to hay and pasture and 50.92 per cent to grain, potatoes and orchards.

Bark thinks it fair to assume that any normal project in southern Idaho will ultimately be devoted to approximately equal areas of the two classes mentioned, and so takes an average of the economic duty found for the grains and the alfalfa on the medium or average soils. The results follow:

Digitized by Google

Average Duty for a Normal Project in Southern Idaho (Bark)

	April.	May.	June.	July.	Aug.	Sept.	Total Season.
Duty in acre feet..	.0194	.3693	.5628	.6504	.3323	.0460	1.9802
Per cent of total..	.98	18.65	28.42	32.85	16.78	2.32	100

Investigations on Experimental Farm at Redmond, Oregon. —In Bulletin No. 119 of Oregon Agricultural College Experiment Station* may be found the results of experiments carried on during the season of 1912 at Redmond, under the supervision of Prof. W. L. Powers, in charge of Irrigation and Drainage Work of the Oregon Experiment Station, who acted as superintendent in direct charge of the Redmond work in 1912. The following is quoted from this bulletin:

Water used on Redmond Farm. —"It should be kept in mind 'states Professor Powers' that the rainfall of the season was about 2 inches above normal as near as can be determined, and that an inch of rain (if it comes in reasonably heavy falls) is equal to more than twice that amount of irrigation water. A good proportion of the place was in cultivated crop and great care was observed in applying water just at the time needed, which, of course, kept down the quantity used. The farm had the advantage of moisture conserving tillage practices, and application of water was governed by the determinations of the soil moisture supply for different crops, and careful measurements of the evaporation and general weather conditions. These latter practices are largely responsible for the relatively small quantity of water used.

The water allowance within this project is 1 8-10 acre feet for the ninety-day season, which for this farm amounts to 3-10 of a second foot continuous flow for the 30 irrigable acres, or a quantity equal to 6-10 acre foot for 24 hours or 54 acre feet for the ninety-day season."

"The quantity and monthly distribution of water used on the Demonstration Farm during the ninety-day period and during the whole irrigation season, as determined by very careful measurements made by the Station employees, is given below. The Station Record was obtained by noting the depth on the weir every couple of hours and recording the exact length of time of flow.

Water Used on Irrigation Demonstration Farm, Redmond. Irrigation Season 1912.

		Acre feet	Acre feet
	April		.875
	May		5.687
Ninety-day	June	8.718	
Irrigation	July	13.257	
Period	August	10.317	
Ninety-day total		32.292	32.292
	September		1.876
Season total			40.730

The 32.292 acre feet used on 31 acres is equivalent to 1.041 acre feet per acre for the ninety-day period, or practically 1 acre foot per acre.

*A report of the Experimental and Demonstration Work on the Substation Farms at Moro, Burns, Redmond and Metolius, by H. D. Scudder, 1914.

Digitized by Google

Relation of Economic Use of Water to Quality and Value of Product.—Irrigation must be carefully applied if the highest quality of product is to be secured. From numerous analyses of potatoes and other products at the State Experiment Station, in connection with other irrigation studies, it appears that where a favorable supply of moisture is maintained it matters not whether this comes from rainfall or irrigation. Wherever more than the moderate amount of moisture is maintained, and where the soil is not allowed to dry out sufficiently to permit the plant to mature its fruit, the composition and keeping qualities of the product are injured. The over irrigated product has as much as 2 or 3 per cent more moisture and a corresponding decrease in percentage of other constituents.

Economic Use of Water and Soil Preservation. —The upland districts of the Central Oregon are fortunate in respect to natural under-drainage and a supply of fresh mountain water for irrigation, so these uplands are not seriously alkaline. However, excessive irrigation water feeds out through the substrata slowly and the excess of alkaline salts that have been carried into the subsoil by centuries of rainfall may be drawn up to the surface by capillarity and cause alkali trouble. Excessive wetting of the soil causes it to set and starts rapid evaporation. Where this evaporation brings up alkali in poorly drained areas, especially the black alkali, it causes crusting of the surface soil, and is injurious to the tender plants. The least possible amount of water should be applied in these places, with furrow irrigation, if possible, and followed promptly by cultivation. On poorly drained and sub-irrigated lands of the irrigated valleys, the alkali is a more serious problem. Cultivation of the surface and very light use of water will help guard against this alkali trouble. The application of well rotted manure to the alkali, or even gypsum to the black alkali spots, will help to neutralize the alkali, but drainage is the real remedy, and under-drainage will undoubtedly pay where these fertile botom lands have become strongly alkaline."

Probable Crops in Future with Extended Irrigation.—Crops grown in the Paulina Marsh district are largely those which may be used in winter feeding of the great numbers of horses, cattle and sheep which find summer range on the marshes, and to some extent on the higher plateaus where bunch grass furnishes excellent pasturage for a short time.

Grain hays are the principal production of Fort Rock and Christmas Lake Valleys, where dry farming is practiced to some extent. Some fair crops of wheat have been raised and threshed in Fort Rock Valley in years when growing conditions were exceptionally favorable.

Owing to the high altitude of these valleys and the danger of killing frosts wheat and alfalfa will probably not be very dependable crops, but it is believed that the hardier grains, such as oats, rye and barley, may be grown successfully under extended irrigation. With the advent of railroad transportation more general farming will no doubt be found profitable, resulting, with better market facilities, in the raising of hogs and development of dairy products. The valuable crops which it is thought can be raised successfully for this purpose with irrigation are oats, barley, timothy, clover, field peas, rape, turnips, rutabagas and mangels.

With regard to the root crops, the following is quoted from Bulletin No. 119 of Oregon Agricultural College Experiment Sta-

Digitized by Google

tion, in which are many valuable suggestions to those undertaking either dry farming or irrigation in the higher parts of Central Oregon.

"Roots are a crop especially successful and well adapted to the diversified irrigated farm, particularly so at the higher elevations, as they are hardy to cold and in these cooler regions obtain a remarkably fine quality of sweetness and crispness. In the sandy loam common to these irrigated lands they find very congenial surroundings where they are not only easily handled but respond generously to applications of manure. Their feeding value for dairy cows and brood sows over winter as well as for other livestock, is very high, not only because of the advantage of their succulence when combined with dry feeds of winter but because of their high digestibility and palatability. It is authoritively stated by Danish investigators that the feeding value of one pound of dry matter of roots about equals that of one pound of any of the common grains."

Water Duty of Different Crops.—The amount of water required in the irrigation of crops varies in different localities. Generally speaking, observations which have been made in Oregon, Washington and Idaho indicate that for grains and cultivated crops, where care is taken to irrigate at the right time, two irrigations of about four inches each, or eight inches, will produce crops almost as great in yield as the application of about eighteen inches, which brings out nearly the maximum yield. The application of more than 24 inches usually gives less yield than for 18 inches.

For alfalfa and other hays and pasture, the duty is variously placed at from 18 to 36 inches. The lower figures are those given by investigators working under ideal conditions, while the higher figures are about the actual uses observed on lands where the supply is adequate and saving of water no great object. The above statements do not relate to the warm arid regions of California, Arizona and New Mexico, where the length of season permits many more cuttings of hay and where the use in some cases reaches as much as 10 acre feet per acre.

Relation of Water Duty to Drainage.—It has been the general experience throughout the West that a liberal use of water in irrigating has resulted in damage to lower lands by bringing the alkalies and other harmful salts to the surface. This has led to the necessity for greater expenditures than anticipated, in constructing drainage canals and in other ways guarding against the trouble. Hence it may readily be seen that the duty of water should be kept as near as may be to actual needs of crops, and care taken in applying only such an amount at each irrigation as can be absorbed in the ground and used by the plants. There is an unavoidable loss from deep percolation, and this water returning to the surface at some lower point is the cause of much damage. Application of too much water at one time tends to increase this loss by deep percolation, and should be avoided as much as possible.

Digitized by Google

Other Factors entering into Determination of Duty.—It has been shown by experiments in many states that fertility of the soil has a great influence on the amount of water required, and that of two soils the less fertile requires more water to produce the same yield as the other. Consequently diversification of crops to maintain fertility will keep down requirements for water.

The character of soil and sub-soil has probably a greater effect on the amount of water required than any other factor. Deep soils of medium texture will require less water than coarse gravelly soils where loss from deep percolation is great. Even a thin layer of porous soil underlying the top soil will cause heavy losses from this source, while hardpan or an impervious strata will cut off much loss of this kind.

Climatic conditions have a marked effect on the amount of water required. The amount and distribution of annual precipitation, humidity of the air and winds have effects which hardly require comment. Investigations in Idaho, already referred to, led to the conclusion that light summer rainfall has little effect on the amount of water required, and is explained by the fact that the atmosphere is normally very dry and that light rains of from one-fourth to one-half inch do not penetrate the soil deep enough to benefit plant roots before the moisture is evaporated.

It is worthy of note that the Klamath Project in south-central Oregon provides for a use of 1.8 acre feet on the land, but that in the season of 1912 when rainfall was above the average, the actual use was only 1.0 acre foot per acre, while in 1911 it was 1.23 acre feet.

The amount of water applied at each irrigation has a decided effect on economic duty. As a concrete example, a tabulation has been made of all the alfalfa plots given in the "Duty of Water Investigations" referred to under "Investigations in Idaho" by Bark, to which the water applied at each irrigation was from 3 to 6 inches, and of those to which from 6 inches to about 12 inches was applied, together with the yields. Only average soils were considered, and those plots in which less than three inches or more than twelve inches was applied at a single irrigation were omitted.

The smaller application, averaging 0.4 of a foot, gave an average yeild of 2.85 tons per acre foot applied, while the application of from 5 inches to one foot, averaging 0.72 of a foot, produced an average of 1.8 tons per acre foot applied.

For the smaller applications, the average applied for the season was 1.8 acre feet and the yield 5.3 tons, while for the heavier applications the average applied for the season was 3.3 acre feet and the yield 6 tons. These figures show conclusively

Digitized by Google

that, for the average soils of that region, the application at a single irrigation should not exceed about 6 inches, and probably about 4½ inches per irrigation would give just as good results.

Value and Economic Use of Water.—Probably in few gravity projects is the consideration of value and economic use of water of greater importance than it is in determining the duty to be assumed for this project. The area of irrigable land is probably four or five times the area which could be irrigated with the available supply of water, using a duty which would give the greatest yield per acre and which might be considered necessary by irrigators who are accustomed to an abundant supply. As an example, let it be assumed that the available supply for a certain project is just sufficient to produce the maximum yield on 40,000 acres, but that by increasing the duty of water 25 per cent there are 10,000 additional acres which can be irrigated with little additional cost, and at less cost per acre for the whole. Assume further that the yield per acre under this increased duty will be reduced only 10 per cent. Then the value of the yield over the entire larger project will be 12½ per cent greater than the maximum for the 40,000 acres. On the other hand, it does not necessarily follow that, because the larger area with the higher duty, or less per acre use of water, produces the greater total yield, the larger project is the better economic project, for while the total yield of the larger project will be greater, the acre yield will be smaller and perhaps less proportionately than the decrease in acre cost of water. Thus the acre yield may fall below that which will adequately compensate for the labor required to produce the yield and for interest on capital invested. In short, the net profits per acre to the smaller holders, whose collective interests are greatest in a project, must reach a certain plane.

The following is quoted from Bark's general summary (See "Investigations in Idaho") as applying to economic duty:

"33. The amount of water that will produce the largest yield of a certain crop on a certain soil is not always the economic Duty.

34. The value of land, the cost of water, the value of the crops produced and the cost of producing them, as well as the amount of water that will produce the largest yield, must all be taken into consideration when determining the economic Duty for any project.

35. Sufficient water for the production of profitable and nearly maximum crops must be delivered to the individuals in order that a project may be successful, but a higher Duty is justified in cases where water is very valuable and land comparatively cheap than where water is cheap and the land is valuable."

Without entering further into the discussion of economic duty for this project, it will be assumed for the purpose of this report that the economic duty for the state will be that duty or use of water which will produce the greatest total yield and yet be such a yield per acre as will reasonably compensate for labor performed, for interest on the investment and taxes paid.

Digitized by Google

The following statements may be made after examining in detail the results of the four years experiments conducted in Idaho.

On soils of poor to average fertility the use of about 1.5 acre feet per acre gives the maximum yield of grain, but the use of half this amount, or 0.75 acre feet, gives a yield only 20 per cent less. In more fertile soil the use of 0.75 acre feet gives about the same yield as 1.5 acre feet in soils of poor to average fertility.

With a high duty of water on this project, grain hay or grains, such as oats and barley, will probably prove a more staple crop than the usual forage crops. If oats is taken as a basis for estimating the value of irrigation, a farmer's books might show something like the following:

Present value of land per acre	$10.00	
Cost of preparing land for irrigation	10.00	
Cost of irrigation project per acre	30.00	
Cost of land with water per acre	$50.00	
Interest on investment, taxes and depreciation on farm improvements @ 10%		$5.00
Cost per acre of plowing, seeding, harvesting, threshing and marketing, per acre, say		8.50
Total cost		$13.50
Value of yield per acre, 40 bu. @ 40¢		16.00
Profit per acre		$2.50

Of course the present value of the land and the cost of preparing it for irrigation may greatly exceed the amounts shown, but on the other hand the yield per acre is not infrequently almost double that used in the illustration.

Duty Assumed for this Report.—In fixing a duty for this report, all the above statements have been given consideration, together with facts brought out in the different investigations by Oregon Co-operative Work or obtained from other sources. In arriving at a definite duty of water for this report, the following assumptions are made conditional on careful preparation of the land and use of a system of rotation in distribution.

1. Two irrigations of four inches each on the land should be the minimum considered for grain and cultivated crops in ordinary years.

2. The allowance for these crops should be nine inches of water at the farm to cover a loss of about 10 per cent in distributing this amount on the land.

3. The short length of season and occasional frosts will probably result in the proportion of land used for alfalfa, clover and other crops of higher water requirements being less than the 50 per cent of the total found advisable in other projects having better climatic conditions.

Digitized by Google

4. Four irrigations of four inches each, or a total of sixteen inches on the land, should be allowed as the minimum economic duty for the latter class of crops.

5. Eighteen inches of water should be delivered to the farm for these crops, to allow for a loss of about 10 per cent in irrigating.

6. The duty of water should be allowed to the entire irrigable acreage on any farm, so that if the irrigator, by economic use of water and skilful handling, should find he can use every available acre, his water allowance will permit this, thus putting a premium on careful use.

Assuming then that about one-third of the land will be used for hay and pasture, requiring eighteen inches of water, and two-thirds for grain and cultivated crops, using nine inches of water, the duty of water assumed for this report is one acre foot on the land per acre of gross area irrigable. Such a duty expressed in tems of net irrigable area, after deducting, say, 15 per cent for lands that might be occupied by farm buildings, roads, fences and corrals, would amount to 1.12 acre feet per acre irrigated. It is believed, however, that the allowance should be for the gross irrigable area, and under this plan a farm of 160 acres, all of which could be irrigated, would be allowed 160 acre feet for the season, notwithstanding the fact that from 5 to 15 acres might be used for building, yards, etc.

SEEPAGE AND EVAPORATION LOSSES.

Seepage and evaporation losses, which occur in reservoirs, canals and distributing systems, are chief among those which take place between water supply and land to be irrigated. Other losses are from breaks in canals, or are due to faulty structures, such as turnouts, measuring boxes, etc. They may be eliminated to a great extent by good design. Evaporation losses are hardly subject to control except in cases of a choice between two reservoir sites having equal capacities where one would expose much less area to evaporation. Such choice seldom occurs. Seepage losses in canals may be controlled to a small degree by designing cross sections which will limit or reduce the wetted perimeter. In some cases where an unusually poor material is encountered the canal may be lined.

Reservoirs.—Seepage from a reservoir is the most uncertain loss. No data are available of loss from constructed reservoirs expressed in terms of area and depth of reservoir. Even were such data available they could hardly be applied to the estimate of loss in other reservoirs whose construction is proposed, as conditions affecting seepage, such as porosity of soil and physical and geological structure of underlying strata, may differ greatly.

Digitized by Google

Seepage losses in reservoirs vary from almost nothing at East Park reservoir in California to 60 per cent or more of the inflow at Deer Flat reservoir in Idaho. It is to be noted, however, that this latter loss was from the reservoir during the first year of its storage period when it was filled to only about one-tenth capacity. For succeeding years, after the underlying soil had become saturated, loss from seepage has been gradually reduced until in the sixth year it amounts to only about 30 per cent. This reservoir is not in a natural water-course and such good conditions for a small loss by seepage could hardly be expected as in the case of a reservoir located in a valley occupied by a natural stream.

Cold Springs reservoir, Umatilla Project, Oregon, has now been operated seven years. The combined seepage and evaporation loss for the last three years has been between 19 and 20 per cent of total inflow. Observations for evaporation indicate that loss due to seepage alone is now approximately 8 per cent of inflow. The estimated seepage loss during the first year of operation was approximately 22 per cent.

Seepage loss from Clear Lake reservoir in Northern California in the same season was 11 per cent. The site of this reservoir includes the former lake from which it takes its name, and consequently the loss by seepage might be expected to be low compared with other reservoirs.

The Thompson Valley site to be used in connection with this proposed project is a natural stream basin. The soil and rocks are of volcanic origin, as are those at the Cold Springs reservoir site. It is believed that conditions at this site are as favorable for a tight reservoir as are those at Cold Springs. In this estimate, however, a seepage loss of 15 per cent of the inflow stored has been allowed. This is nearly double that of Cold Springs reservoir after seven years operation. The Thompson Valley reservoir is 600 feet higher in elevation than the proposed diversion from Silver Creek near the town of Silver Lake. Some return seepage from the reservoir loss would certainly reach Silver Creek above the diversion point. No allowance has been made for this, so that a net loss of 15 per cent from the Thompson Valley reservoir above any return seepage to the stream below is provided for in the estimate.

Evaporation from the surface of reservoirs has been made the subject of considerable study by engineers. Conditions affecting evaporation from a free water surface are temperature, wind, relative humidity of the atmosphere over the surface, and depth of water. It is practically impossible to make conditions in any experiment conform to those which actually obtain throughout the season with different depths of water in the reservoir. Experiments have been made with evaporation pans so

Digitized by Google

placed in the ground that their water surface is even with it. Results obtained from these experiments can hardly be considered a true index to the evaporation from the surface of a large body of water. The general opinion is that results obtained are too high. Records of evaporation from pans were kept at Moro, Oregon, in the years 1911, 1912, 1913 and 1914 during the months from March to November. The total amounts of evaporation for the years in the order given are 51.4, 42.8, 40.6 and 42.9 inches, an average of about 45 inches for the four years. Records kept at Burns, Oregon, during the summer of 1914 from April to October inclusive, gave a total evaporation of 42.9 inches. Measurements of evaporation from the free water surface of Clear Lake in Northern California, made by the Reclamation Service during seven months in 1911, showed a total loss of 3.43 feet, distributed by months as follows:

April	May	June	July	Aug.	Sept.	Oct.
2″	·3″	6″	9″	10″	7″	4″

During most of the remainder of the year the lake was frozen over and there could not have been very much evaporation. Evaporation from a free water surface is generally thought to range from about three feet in higher altitudes to about six feet in lower altitudes in the western part of the United States.

Thompson Valley is located at an elevation of 5,100 feet above sea level, and it is believed that evaporation there will not much exceed this lowest estimate. Three feet has therefore been allowed for evaporation from the surface of reservoirs considered in this estimate, distributed as follows:

	Jan.	Feb.	Mar.	Apr.	May	June	July
Feet	.030	.069	.186	.375	.402	.396	.450
Per cent of total	1.0	2.3	6.2	12.5	13.4	13.2	15.0
	Aug.	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Total**	
Feet	.519	.345	.141	.057	.030	3.000	
Per cent of total	17.3	11.5	4.7	1.9	1.0	100	

Canals.—Determination of seepage losses in a great number of canals has demonstrated that they are nearly proportional to wetted area of canal and that the depth of head slightly affects these losses within the limits of canals of ordinary capacity.

It can readily be seen that in a small ditch the proportion of wetted area to its carrying capacity, and in consequence the percentage of loss per mile, is much greater than in the case of a large canal.

No more comprehensive investigation of losses in canals of all sizes has been made than the investigation in Idaho by Bark, already referred to. The investigation was carried through two

Digitized by Google

seasons and losses were determined from 118 sections of different canals. These canals had a total length of 300 miles and ranged in size from the smallest farm laterals up to the main canal of the Twin Falls Southside Project, carrying about 3,100 second feet. The following statements relating to canal losses are quoted from Bark's summary:

"The expression of seepage losses as per cent of loss per mile is misleading."

"Seepage losses should be expressed as the unit of loss per unit of wetted area of canal bed per unit of time."

"Evaporation losses from canals are negligible."

"The percentage of loss is extremely high in small laterals carrying one second foot or less."

"Losses from canals in medium soil range from 0.5 of a cubic foot to 1.5 cubic feet per square foot of canal bed per 24 hours."

"Porous irrigated land above a canal may cause it to gain instead of lose."

In this project, the surface soil is thought to be of fairly tight structure as indicated by the compactness of the roads found quite generally throughout the Silver Lake and Fort Rock valleys. Seepage losses from canals and laterals are estimated at one cubic foot per square foot of canal bed for 24 hours. Some exceptions to this have been made where it is thought more previous soils will be encountered. In such cases one and one-half cubic feet per square foot of canal bed for 24 hours have been allowed. These exceptions will be noted under descriptions of the different canals. Seepage losses are taken to include evaporation from the surface of canals, which in ordinary cases has been estimated to be not greater than one-tenth of one per cent.

PROPOSED PROJECT.

It is proposed: First, to divert waters of streams entering Sycan Marsh over a low divide separating Sycan Marsh and Thompson Valley, by means of two diversion canals. The Sycan Canal will divert waters of Sycan River about two miles above the marsh and run north and west along the borders of the marsh to the low divide mentioned above, where it will discharge into a stream entering Thompson Valley. The length of this proposed canal is about 14 miles. It will divert the waters of Chocktoot Creek at its crossing of that creek. The Long Creek Canal as proposed is about 6.1 miles long, and will divert waters from Long and Coyote Creeks to the above mentioned divide, where it will join the Sycan Canal and discharge into Thompson Valley reservoir. See Sheets Nos. 34, 38 and 39.

Second, to provide storage in Thompson Valley for waters diverted from Sycan Marsh drainage in the months before irrigation begins, together with waters entering Thompson Valley from tributary streams. See Sheet No. 22.

Digitized by Google

Third, to construct a dam on Silver Creek about two miles southwest of the town of Silver Lake, for diversion of these stored waters into two main canals, after release from the Thompson Valley Reservoir about ten miles above. These canals take out, one at each end of the dam. See Sheet No. 34.

Fourth, to construct the Silver Lake canal, diverting from the east end of the dam and extending easterly towards Silver Lake, a distance of about eight miles, for the irrigation of 7,500 acres hereinafter called the Silver Lake Unit.

Fifth, to construct the West Canal, diverting from the west end of the dam and running in a northerly direction around the west side of Paulina Marsh and the west slope of Fort Rock Valley. This canal will be about 32 miles long and serve three units as follows: The Paulina Unit on the west slope of Paulina Marsh, 9,000 acres; the Horning Bend Unit, 10,800 acres; and the Fort Rock Unit, 21,300 acres.

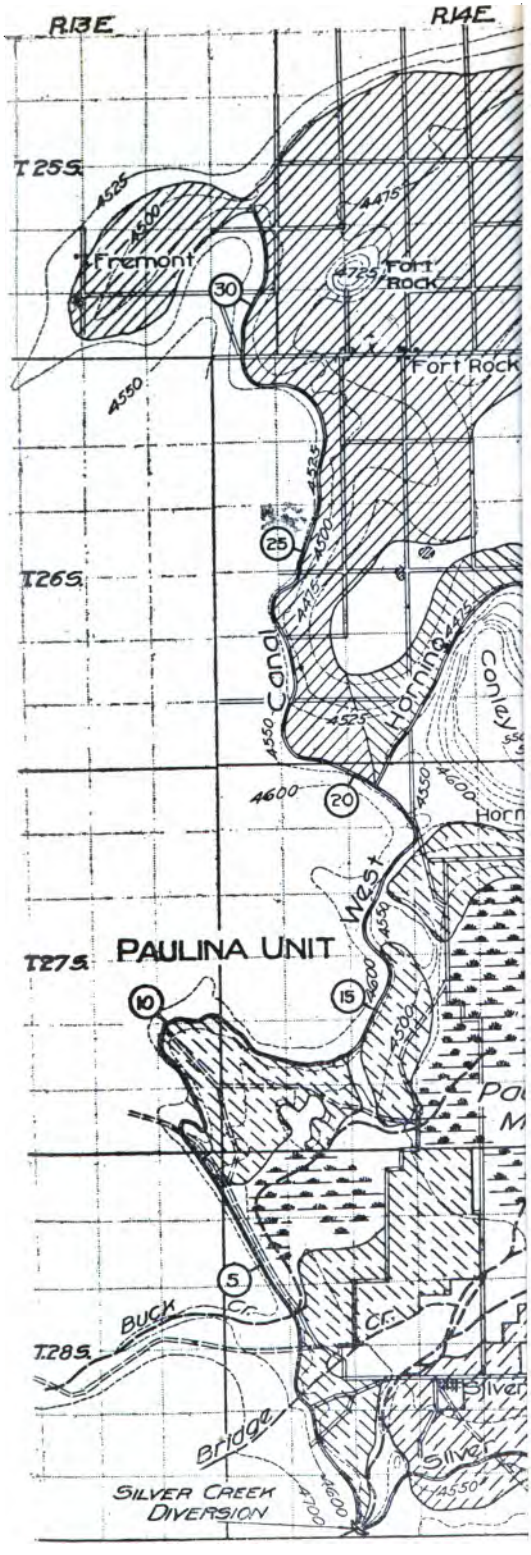
The total irrigable land to be served by the West Canal will be 41,100 acres, and by the Silver Lake Canal, 7,500 acres, a total of 48,600 acres for both canals. Also, in addition to an amount equal to the natural flow of Silver Creek in a mean year, already set aside for the satisfaction of adjudicated rights, 4,000 acre feet yearly from Thompson Valley storage will be allowed to pass the diversion dam during the irrigating season, to serve about 8,000 acres of land lying between the Silver Lake Unit and Paulina Marsh, owned by holders of these rights.

Water Required.—The assumed use of water during the irrigating season, May 5th to August 12th, measured at the land and expressed in feet of depth, is as follows:

May	June	July	August	Total
.16	.37	.35	.12	1.0

Assumed seepage losses in distributing laterals have varied from 5 per cent to 25 per cent, depending upon the size and shape of the unit to be served. Present practice, where the duty of water is high, indicates that in order to distribute water in an economic manner a system of rotation is advisable, and the smallest irrigating head used should not be much less than 10 cubic feet per second. Accordingly an estimate has been made of all the small laterals required in the Silver Lake Unit to carry the water down to each forty acre tract. All laterals 20 second feet or greater in carrying capacity are estimated to run full during the month of maximum use, and smaller laterals are estimated to run for only so much of the month as is necessary to serve lands under them. Seepage loss in the laterals is taken at one cubic foot per square foot of wetted area per 24

Digitized by Google



Digitized by Google

Digitized by Google

hours. An additional allowance is made for wetting up all 10 second foot distributing laterals to a depth of one foot over the wetted area three times during the month.

The Silver Lake canal, as estimated, will reduce in capacity to about 20 sceond feet, at a point about four miles from the head of the canal. The canal loss to this point, allowing one cubic foot per square foot of wetted area per 24 hours in earth section, and one inch in depth from each square foot of wetted area per 24 hours in lined section, amounts to 5.8 per cent of the diversion ,while that from the distributing system, taken to include the main canal beyond the four mile point, amounts to 9.4 per cent of the diversion, a total loss from diversion to land of 15.2 per cent.

A separate estimate has been made for distribution loss to 3,000 acres of this unit, and from this a scale of percentage loss in distribution obtained which can be applied to units of varying size throughout the project. Estimating in this manner for the West Canal, the average distribution loss from canal to lands is found to be 13 per cent, and the canal loss from diversion to end of canal 14 per cent, making a total loss of 27 per cent from diversion to lands.

With these assumptions, the monthly requirements at diversion, expressed as depths in feet per acre, for the two canal systems are as follows:

	May	June	July	August	Total
Silver Lake Canal	.189	.435	.414	.142	1.180
West Canal	.220	.507	.480	.164	1.370

The total acre feet required each month at diversion are as follows:

	May	June	July	August	Total
Silver Lake Canal	1,420	3,260	3,100	1,070	8,850
West Canal	9,040	20,840	19,730	6,740	56,350
Total Project	10,460	24,100	22,830	7,810	65,200

It will be seen from this tabulation that the June requirements and consequently determine the size of canals. The Silver Lake Canal will have to divert 55 second feet, the duty at diversion being one second foot to 136 acres. The West Canal will require a capacity of 350 second feet, and the duty at diversion will be one second foot for 118 acres.

A more detailed description of diversion canals, reservoir sites and distributing systems will be taken up under "Construction Designs and Estimates."

Water Supply.—The water supply required for the project as proposed will all come from Silver Creek above Thompson

Digitized by Google

Valley and from waters diverted into Thompson Valley from the Sycan tributaries by the Sycan and Long Creek canals, storage to be provided for waters entering Thompson Valley reservoir before May 5, the opening date of the proposed irrigating season.

From an investigation of Sycan Marsh in March of this year (1915) and from local information as to the comparative advance of the spring season in previous years, it is thought that diversion of the waters of the Sycan tributaries, through the proposed diversion canals, could be begun, on the average, about the middle of March. Sycan Marsh with its tributary streams forms the head waters of Sycan River, a branch of the Sprague River which in turn enters Williamson River at Chiloquin. Williamson River is one of the streams entering upper Klamath Lake. It is probable that additional development of irrigation projects on these lower streams and from Klamath Lake may necessitate the storage of water from Sycan Marsh during the summer months of low run-off, but it is believed the diversion to Thompson Valley from tributaries of the Sycan, prior to about the middle of June will not materially affect further development, below the marsh, of irrigation use from the streams mentioned. For purposes of this estimate, June 15 has been taken as the time after which no diversions will be made from streams tributary to Sycan Marsh. The following is a tabulation of probable discharge of the Sycan tributaries during the time in which it is proposed to divert them, and probable delivery to Thompson Valley by diversion canals having capacities as proposed. See Sheet No. 40 for the estimated discharge of these streams.

Digitized by Google

March 15 to June 15*

Year.	Sycan River and Chocktoot Creek.	Estimated delivery of Sycan Canal to Thompson Valley.	Long and Coyote Creeks.	Estimated delivery of Long Cr. Canal to Thompson Valley.
	Acre feet.	Acre feet.	Acre feet.	Acre feet.
1903–04.....	120,000	58,000	45,000	36,000
1904–05.....	28,800	25,800	11,500	10,300
1905–06.....	74,200	48,200	28,000	25,400
1906–07.....	105,400	56,500	42,000	34,400
1907–08.....	41,000	30,000	17,000	15,200
1908–09.....	73,100	49,700	28,600	26,000
1909–10.....	48,800	40,500	20,600	18,200
1910–11.....	80,200	51,200	31,500	28,200
1911–12.....	54,500	34,900	23,400	21,700
1912–13.....	61,100	43,900	22,900	20,900
1913–14.....	61,600	48,100	24,400	22,200
1914–15.....	21,100	18,000	8,500	7,440
Total.....	769,800	504,800	303,400	265,940
Mean.....	64,150	42,000	25,300	22,160

*March 15 to end of month estimated at .7 of March discharge, and June 1 to 15 is estimated at .6 of June discharge.

It should be noted that the difference between the parallel columns in the above table is due to deduction for estimated losses past diversion at the heads of the proposed diversion canals such as waste, and to seepage losses in the canals themselves.

Following is a tabulation of the estimated mean yearly inflow to Thompson Valley from all sources, available both for storage and use without storage, for the proposed project.

	Non-irrigating Season Acre feet	Irrigating Season Acre feet	
Silver Creek	18,100	1,000	
Sycan Canal	22,000	20,000	
Long Creek Canal	11,800	10,400	
Total	51,900	31,400	
Total for year		83,300	acre feet
Reservoir Losses:			
*Seepage, 15% of 63,300 acre feet,	9,500	acre feet	
Evaporation, 1,900 acres at 3 acre feet	5,700	" "	
		15,200	acre feet
Available for storage		68,100	" "
Storage required by 8,000 acres hay lands		4,000	" "
Available for use on new lands		64,100	" "

*Seepage here estimated is taken at 15 per cent of the inflow actually stored. See "Storage Requirements."

Storage Requirements.—Storage will be required at Thompson Valley for all the inflow up to the irrigating season and excess of inflow during May and June over uses proposed during those months. Following is a tabulation of estimated inflow and use as affecting the question of storage at Thompson Valley:

Digitized by Google

Period	Inflow Acre feet	Use Acre feet	Storage required Acre feet
Sept. to May 4	51,900	None	51,900
May 5 to May 31	22,000	10,600	11,400
June 1 to June 15	9,350	12,850	
Total necessary to store			63,300
Reservoir losses in storage period:			
Evaporation, 1,900 acres at 1.5 acre feet		2,850 acre feet	
Seepage, 10% of 63,300 acre feet		6,300 " "	
			9,150
Required storage capacity			54,150
Reservoir losses during year		15,200 acre feet	
" " storage period		9,150 " "	
" " irrigating period		6,050 " "	
			6,050
Storage available for diversion			48,100

It will be seen that under the assumptions as to seepage and evaporation losses in the reservoir, storage capacity is required at Thompson Valley for 54,150 acre feet in a mean year, on the basis of providing for no carry-over storage from a year of high run-off to a low year.

PROPOSED STAGES OF DEVELOPMENT.

The proposed project as outlined above presents exceptionally good conditions for development by stages. While the cost of constructing the project by stages as outlined herein may be greater than for the development of the whole project at once, the saving in interest during the years which will naturally intervene between stages of development will probably more than offset the difference in cost. Cost of development by stages will be taken up under "Construction, Designs and Estimates."

Silver Lake Unit.—Irrigation of the 7,500 acres under the Silver Lake Unit will naturally come first and will involve the following features:

First, construction of a storage reservoir at Thompson Valley for the storage of available waters of Silver Creek, which have been shown, under supply available from Silver Creek, to furnish about 9,000 acre feet at diversion, for use on new lands. Water requirement for the Silver Lake Unit, as shown above under the assumed duty of water of one acre foot per acre on the land, is 8,500 acre feet. The storage capacity required for this supply, including the 4,000 acre feet to be furnished the Paulina Marsh hay lands, is about 15,600 acre feet.

Second, construction of a diversion dam on Silver Creek as Planned for the completed project.

Digitized by Google

Third, construction of the Silver Lake Canal as described under "Proposed Project."

Fourth, construction of the distributing system for the Silver Lake Unit.

Paulina Unit.—The second stage of development naturally suggests the construction of the West Canal to the divide between Paulina Marsh and the west end of Fort Rock Valley, and the irrigation of the Paulina Unit. The water supply required for this development must come from a partial development of the Sycan water supply, as the Silver Lake Unit requires the full amount available from upper Silver Creek.

The Paulina Marsh Unit, with an irrigable area of 9,000 acres, will call for about 9,000 acre feet of water at the land during the season, which with an estimated loss of 25 per cent between diversion and the land will require 12,000 acre feet at diversion.

The Long Creek Canal as planned for the proposed project is estimated to deliver to Thompson Valley about 22,000 acre feet between March 15 and June 15 of a mean year. It is believed the portion of this occurring after May first will be at least 12,000 acre feet, and thus no storage will be required in Thompson Valley other than that proposed for the Silver Lake Unit.

Horning Bend and Fort Rock Units.—The third and last stage of development will be completion of additional features of the project as proposed, and is as follows:

First, final development of Thompson Valley storage by raising the east or main dam, constructing a new spillway and building the west dam. The detailed description of the stages of development of Thompson Valley storage will be taken up under "Construction, Designs and Estimates."

Second, construction of the Sycan Diversion Canal.

Third, completion of the West Canal and the Horning Bend lateral, as well as the distributing system required under these extensions.

POSSIBLE EXTENSIONS.

Paulina Marsh Reclamation.—The reclamation of Paulina Marsh, especially that part tributary to Buck Creek where it first enters the marsh, together with the northern part of the marsh, comprising in all about 9,100 acres of irrigable land, can best be accomplished by storage of all the available supply on Buck Creek during the non-irrigating season and the use of the waters thus stored, together with the direct flow of the stream, during the irrigating season. The distributing system (See Sheet No. 34) would be built up as follows:

Digitized by Google

First, a small diversion from Buck Creek near the crossing of the country road in Section 17, T. 28 S., R. 14 E., and a canal following about the 4,475 foot contour around the northern border of that part of the Paulina Unit lying between Bridge Creek and Buck Creek, for the irrigation of 2,500 acres between this diversion canal and Buck Creek to the north.

Second, a lower diversion from Buck Creek at about the center of Section 33, T. 27 S., R. 14 E., and canal following about the 4,450 foot contour around the northern border of 6,600 acres comprising the north end of Paulina Marsh, this canal having about 75 second feet capacity at diversion and a length of nine miles.

Third, a lateral of 30 second feet capacity, commencing on the south side of Buck Creek, from the same diversion as in the above division No. 2, and extending about two and one-half miles east, to serve that portion of the 6,600 acres lying on the south side of Buck Creek.

Drainage for Paulina Marsh would be provided by a canal extending from the inlet to Silver Lake from Paulina Marsh up the old drainage channel from Paulina Marsh in a northwesterly direction to about the southwest corner of Section 24, T. 27 S., R. 14 E., thence southwesterly, following the present channel of Buck Creek to the lower diversion point, near the center of Section 33 already mentioned. Above this diversion point the present channel of the stream would be deepened and used as a drainage channel for the 2,500 acre division, as well as to carry the greater part of the water supply from the mouth of the Buck Creek Canyon at the upper diversion down to the lower diversion. From the lower diversion point the drainage canal is estimated to require a capacity of 30 second feet at its head, gradually increasing, in the ten and three-quarters miles to Silver Lake, to 120 second feet. The combined drainage and feed canal above the lower diversion point is estimated to have a capacity of 80 second feet.

Water Supply.—A preliminary study of storage possibilities on Buck Creek at the Emory reservoir site made it seem advisable to provide storage capacity for an annual use of 14,000 acre feet from this stream, which amount requires holding over the excess in years of high run-off. The above conclusion was based on two considerations.

A natural depression in the ridge forming the lower end of the Emory reservoir site, at an elevation of 4,642 feet, presents an opportunity, with the higher water surface required under the hold-over plan, for a cheap spillway with crest not more than five or six feet below this ground elevation, and with the added desirable feature that the spillway will be independent of the dam structure. If hold-over storage is not provided the esti-

Digitized by Google

ated storage capacity required for developing the use of the ean yearly run-off is about 9,000 acre feet. This brings the aximum water surface to an elevation of 4,632 feet, which ›uld necessitate a long cut reaching a maximum depth of about feet at the spillway site mentioned. This would be more ensive than a spillway around the west end of the proposed m, but more desirable from the standpoint of safety. The timated cost of the development of 9,000 acre feet of storage th water surface at 4,632 feet elevation is $15 per acre foot ailable for use. The second consideration is that hold-over ›rage at Buck Creek would aid in the control of discharge into lver Lake during years of high run-off. This regulation of in- w is necessary in order to keep within economic limits, the st of a dike and overflow channel to be provided in connection th a reservoir, embraced in a plan, hereafter proposed, for the clamation of the bed of Silver Lake.

The storage required under this plan of holding over from ar to year is 12,000 acre feet, as will be shown in the follow- g study of use, reservoir losses, carry-over and shortage dur- g the period 1903-04 to 1914-15. Seepage losses, with the ex- ption of those in 1903-04, have been taken at 15 per cent of rry-over plus inflow stored from October 1 to April 15 of the cceeding year, this amount including allowance for any evap- ation from the reservoir during the irrigating season. The in- ›w during this period, October 1 to April 15, is taken at 45 per nt of that for the entire seasonal year. Evaporation losses are sumed at three feet in depth over the mean area submerged ch year. See Sheet No. 23 for area and capacity curves of the ›posed reservoir site and location of the Emory dam site.

Estimated reservoir losses, carryover and shortage from Buck Creek Storage, Emory Reservoir, with yearly use of 14,000 acre feet.

t. 1 to pt. 30 ear.	Discharge for year, acre feet.	Inflow plus carry-over acre feet.	Reservoir Losses.		Available for use acre feet.	Carry-over to next year, acre feet.	Shortage %
			Seepage acre feet.	Evaporation. acre feet.			
03-04	27,600	27,600	*1,970	1,460	24,170	10,170	0
04-05	10,000	20,170	2,200	1,700	16,270	2,270	0
05-06	13,330	15,600	1,240	1,080	14,380	380	0
06-07	26,000	26,380	1,810	1,450	23,120	9,120	0
07-08	10,400	19,520	2,070	1,680	15,770	1,770	0
08-09	17,100	18,870	1,420	1,200	16,250	2,250	0
09-10	21,320	23,570	1,780	1,350	20,440	6,440	0
10-11	17,400	23,840	2,140	1,560	20,140	6,140	0
11-12	12,500	18,640	1,770	1,560	15,310	1,310	0
12-13	12,400	13,710	1,020	1,200	11,490	0	18
13-14	14,700	14,700	990	900	12,810	0	8.5
14-15	5,300	5,300	350	300	4,650	0	66

*See special study for this year, to follow.

Digitized by Google

An examination of the third and seventh columns of the above tabluation indicates that the greatest storage capacity required during the period considered, in order to waste no water during flood period, would have been in the year 1903-04. The greatest shortage during the period would be in the present year, 1914-1915, but any considerable decrease in the yearly use resulting in carry-over from the previous high years through three years of comparatively low run-off would involve large losses by evaporation and seepage in the reservoir and also involve losses over the spillway during the period 1903-04 to 1910-11 unless the capacity of the reservoir were greatly increased. Hence it appears under the assumptions made in the tabulation above as to reservoir losses that the economical use allowable is about 14,000 acre feet. Accordingly a detailed study of the required storage capacity during the high year 1904, assuming a yearly use of 14,000 feet, has been made as tabulated below.

Storage Capacity required at Emory Reservoir year 1903-04. Estimated inflow 27,600 acre feet; assumed use 14,000 acre feet.

Period.	Inflow. acre feet.	Inflow and balance from previous month, acre feet.	Reservoir Losses.		Use, acre feet.	Total draft, acre feet.	Balance in reservoir acre feet.
			Seepage. acre feet.	Evaporation, acre feet.			
Sept. 1 to April 15..	12,750	.....	*1,240	410	.....	1,650	11,100
April 15 to April 30..	1,300	12,400	65	95	2,460	2,620	9,780
May.....	5,100	14,880	250	210	5,050	5,510	9,370
June.....	5,650	15,020	280	215	3,130	3,625	11,395
July.....	2,300	13,695	115	250	1,820	2,185	11,510
August....	500	12,010	20	280	1,540	1,840	10,170
Total....	27,600	.....	1,970	1,460	14,000	.....	.....

*Seepage during the storage period is taken at approximately 10 per cent of the inflow, and at 5 per cent during the irrigating season.

It will be seen from the above that the greatest storage capacity required was during the month of July, when there would have been about 11,500 acre feet in the reservoir. The maximum water surface elevation required in the reservoir for this capacity is 4,637 feet, and about 600 acres would be flooded.

Assuming that the reclamation of Paulina Marsh would follow the development of the Paulina Unit of the project proposed, the source of water supply for the irrigation of Paulina Marsh from Buck Creek would be augmented by return seepage to the distributing canals from the irrigation of the Paulina Unit, lying above them, as well as from the canal losses under the West Canal. The total water supply is estimated as follows:

Digitized by Google

Estimated Water Supply---Paulina Marsh Reclamation

From Buck Creek with Storage at Emory site	14,000	acre	feet.
" return seepage West Canal and Paulina Unit losses	1,850	"	"
" return seepage between upper and lower diversions of Buck Creek	820	"	"
Total estimated yearly supply	16,670	"	"

This supply for 9,100 acres at diversion would give a diversion duty of 1.83 acre feet per acre.

Silver Lake Bed Reclamation.—There are about 10,400 acres in the bed of Silver Lake which proved to be very fertile when in 1889, following two years of low run-off, part of the bed was farmed. Early settlers report that excellent crops of grain were raised.

The inflow to Silver Lake from Paulina Marsh (See Water Resources) has been estimated at from 15,000 to 20,000 acre feet in a mean year. This may be as great as 50,000 acre feet in years of high run-off, such as 1903-04 and 1906-07. The reclamation of the bed of the lake, without controlling the streams entering Paulina Marsh by means of storage, cannot be considered, on account of the impracticability of disposing of the inflow in high years.

The proposed Silver Lake project when completed will provide the necessary control of upper Silver Creek by storage at Thompson Valley. Except in the cold winter months when the run-off from Silver Creek is very light, the excess water coming from lower Silver Creek can be controlled by diverting through the West Canal and wasting into Fort Rock Valley. There still remains the spring run-off from Bridge and Buck Creeks to control. The development outlined for the reclamation of Paulina Marsh, involving hold-over storage on Buck Creek at the Emory reservoir site, will provide control for Buck Creek. The spring run-off from Bridge Creek drainage area finding its way to Silver Lake in a high year is comparatively small.

From these considerations, it is thought the reclamation of the Silver Lake bed can best be accomplished after the development, already outlined, of the Silver Lake Unit, Paulina Unit and Paulina Marsh reclamation, by storage in a part of Silver Lake.

There will undoubtedly be some return seepage from lands irrigated under the Silver Lake and Paulina units, and from canal losses during the irrigating season, but on account of the nature of the soils and the small quantity of water per acre provided for irrigation, it is hardly to be expected that this return seepage will amount to more than 20 per cent of the water diverted for use on these lands. Assuming that the return seepage will amount to 15 per cent, or approximately 9,000 acre feet, per annum, it will not all find its way to Silver Lake in the irrigating season, but will be spread throughout the year, especially those

Digitized by Google

waters which reach the drainage channels by deep percolation. Return seepage during the irrigating season will undoubtedly be a greater proportion of the total for the year than is the length of the irrigating season to a full twelve months, due largely to the waste from the ends of laterals during the irrigating season. In this estimate return seepage during the irrigating season will be taken at one-third of the estimated yearly total. This estimated return seepage, one-third of 9,000 acre feet, or 3,000 acre feet, will supply water for but a small portion of the bed of Silver Lake and must be augmented either by further storage on lower Silver Creek and on Bridge Creek, or by allowing their waters to flow to Silver Lake and there be stored.

The Egli reservoir site on lower Silver Creek was found to be inadequate for control of Lower Silver Creek, as the maximum storage capacity is only about 3,500 acre feet and the acre foot costs in excess of $20.00 per acre foot stored. The Owsley site, while estimated to have storage capacity sufficient for the control of Bridge Creek, would probably have an excessive acre foot cost and is not considered feasible. It then seemed desirable to determine the character of the bed of Silver Lake to find out if there were a portion which could be used as a storage reservoir, from which water could be pumped for irrigating the balance of the lake bed. A hydrographic survey of the bed of lake was made for the Oregon Co-operative Work by Paul V. Hodges, of the U. S. Geological Survey, in July, 1915. He also determined the relation between the gage established by the Geological Survey and the Reclamation Service datum, established by the survey made for this report. Mr. Hodges, with one assistant, took about fifty soundings, scattered over the central portion of the lake bed, as described in the following quotation from his report:

"To obtain the topography of the lake bed, soundings were taken and located in the following manner: By means of triangulation the elevation above the lake of a point on the rim rock bordering the west side of the lake was determined. The high point is located in lot 3, sec, 11, T. 29 S., R. 15 E. An assistant was sent out in a boat with a calibrated rod, and instructed to take a sounding about every 1,000 feet. When a sounding was to be taken the assistant in the boat would hoist a red flag. With the instrument located at the high point I would take two readings of the vertical, or depression angle—one direct reading and one with the instrument reversed so as to eliminate any error of the vertical circle. The magnetic bearing was also obtained for each sounding.

Knowing the height of the point above the lake, the distance from the instrument to the boat was obtained by dividing the height of the point by the tangent of the vertical angle. On the accompanying map of Silver Lake I have plotted the location of the soundings taken. These soundings show that the lower part of the lake bed is very flat, and does not vary much from a uniform depth of about 3.8 feet.

There is not much land exposed along the edge of the lake. On the west side, about one mile below F. D. Duncan's ranch, there is a strip under cultivation about 100 to 150 feet in width. and about three-quarters of a mile long. Since this strip was planted the lake has receded and left an-

Digitized by Google

other strip about 100 feet wide next to the lake. From observation I would judge that this represented about an average of the land exposed along the edge of the lake by the receding water.

A sample of the water of Silver Lake was taken well out near the center of the lake. This sample was taken well below the surface, and at a place where there were no weeds growing.

Also a sample of the soil on the border of the lake was taken about one mile below F. D. Duncan's ranch. A hole was dug to a depth of three feet and the soil from different depths was well mixed together. From this mixture the sample was taken.

In digging down the three feet the following strata were encountered.

3 inches silt and sand

1 foot black loam soil

1–¾ foot light gray clay and sand mixed with loam."

This field investigation by Mr. Hodges brought out the fact that the bed of Silver Lake is much like a shallow saucer, and that its reclamation, wholly or in part, will involve pumping the drainage water from lands to be reclaimed, not only during the irrigating season but during a large part of the non-irrigating season as well.

The investigation further revealed that the surface of the lake bed is too uniform to afford the large natural sump desired, and that storage must be provided in an artificial reservoir.

The plan of dyking off a portion of the north end of the lake to provide storage for the waters of the remainder is a solution of the difficulty, provided the seepage, passing through deep layers of pervious strata from the reservoir thus formed, to the lands to be reclaimed, be not excessive.

Van Winkle's explanation of the freshness of Silver Lake water as being due to frequent dessiccation of the lake and subsequent deposition of an impervious layer of silt which prevents later inflow from dissolving the deposited salts, would seem to indicate that if the strata were exposed at different portions of the lake bed they would be well covered by impervious silt deposits. If such is the case, it is thought a dyke well bonded to the lake bed would not be impracticable in reclaiming it in part.

The following outline of a plan for reclaiming about 6,500 acres of the bed of Silver Lake is offered as a possible extension of the Silver Lake project and Paulina Marsh reclamation:

1st. Development of power on Silver Creek to the amount of about 225 horse power, and construction of a transmission line to a pumping plant on the east shore of Silver Lake.

2nd. Construction of a dyke across Silver Lake from about the northeast corner of Sec. 3, T. 29 S., R. 15 E., on the west shore of Silver Lake, to about the center of Sec. 30, T. 28 S., R. 16 E., on the northeast shore of Silver Lake, to an elevation of 4,440 feet, or 10 feet above the lowest point in the bottom of Silver Lake.

3d. Excavation of a channel about 14,000 feet long extending from the east end of the dyke to Thorn Lake, to waste

Digitized by Google

excess inflow in years of high run-off. Drainage water from the 6,500 acres reclaimed will be pumped into this channel whenever it becomes too alkaline for use.

4th. Construction of a pumping plant at the east end of the dyke to pump water from the reservoir to the feed canal, a maximum lift of about 12 feet, and to pump drainage water from the 6,500 acres either to the distributing or to the waste canal.

5th. Construction of a distributing canal from the pumping plant, around the east and south borders of the lake for a distance of about nine miles, and distributing laterals to serve the 6,500 acres to be reclaimed.

Water Supply—Return seepage from Paulina Marsh consequent on the irrigation of 18,000 acres of marsh lands, and 16,500 acres bordering on them, is estimated at 15 per cent of the water diverted to the lands, or about 9,000 acre feet. The direct flows of lower Silver Creek and Bridge Creek, which have not heretofore been drawn upon for irrigation, are also used. The total supply available for the reclamation of the bed of Silver Lake, in a mean year after the Silver Lake project and the Paulina Marsh reclamation have been developed, is estimated as follows:

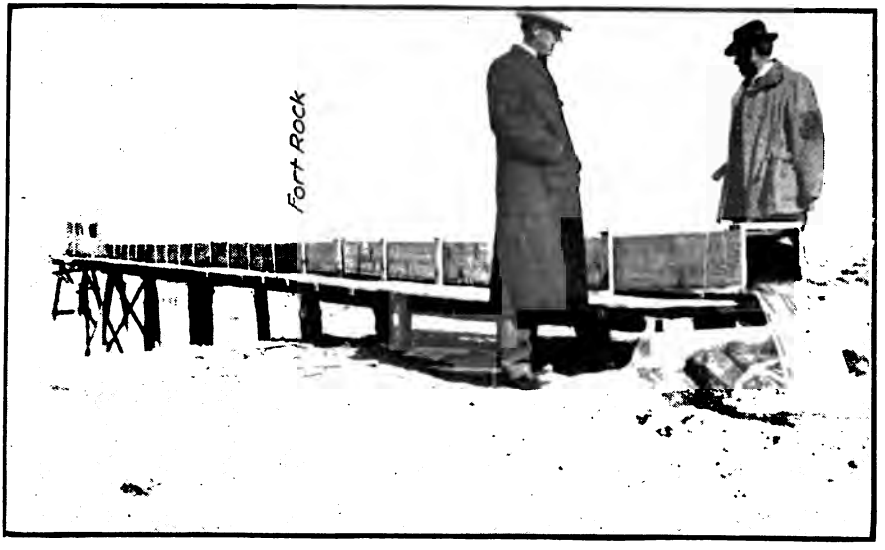
Estimated mean yearly water supply for Silver Lake (lake) reclamation.

Non-irrigating season—Sept. 1 to Apr. 30		
Direct flow from lower Silver Creek	6,800	acre feet
Direct flow from Bridge Creek	1,600	" "
Return seepage, Paulina Marsh, two-thirds of year, 2/3 of 9,000 acre feet	6,000	" "
	14,400	" "
Reservoir loss—evaporation, 2,000 acres @ 1.5 acre feet	3,000	" "
In reservoir at beginning of irrigating season	11,400	" "
Irrigating season—May 1 to Aug. 31		
No direct flow available.		
Return seepage, Pauline Marsh, one-third of year, 1/3 of 9,000 acre feet	3,000	" "
	14,400	" "
Evaporation, May and June, 2,000 acres @ 1.25 acre feet	2,500	" "
Total available for pumping and irrigation	11,900	" "

The supply of 11,900 acre feet estimated to be available in a mean year would give a duty at diversion of 1.82 acre feet per acre on the 6,500 acres.

Pumping to Additional Lands—Fort Rock Valley.—The possibility of developing summer power on Silver Creek following storage development at Thompson Valley, and the probability of increasing the ground water supply in Fort Rock Valley by the

Digitized by Google



PUMPING FROM A WELL IN FORT ROCK VALLEY PLATE 7

SILVER LAKE (TOWN) LOOKING WEST PLATE 8

Digitized by Google

Digitized by Google

proposed irrigation of about 32,000 acres of bordering lands, suggests the possibility of pumping for the irrigation of additional lands in Fort Rock Valley.

The ground water level throughout this valley has been discussed under "Wells and Domestic Supply," and shown to be at a depth ranging from a few feet to about 35 feet. The question of whether large quantities of this ground water supply could be pumped from wells for irrigation depends upon the source of the supply from which this ground water comes as well as the character of the substrata from which it would have to be pumped.

It is estimated that there are about 1,000 square miles of territory lying to the north and west of Fort Rock Valley, reaching about 30 miles to the Paulina Mountains on the north and about the same distance to the Walker Range on the west, which have no surface run-off. This territory slopes toward the Fort Rock desert, and at some time may have drained into the lake which formerly occupied the present Fort Rock Valley. Some evidence of this was noted in the vicinity of Fremont, where several canyons with dry stream beds enter the small Fremont Valley, from which there is a well defined canyon entering Fort Rock Valley about two miles northwest of Fort Rock. See Sheet No. 19.

Assuming that the mean annual rainfall over the area described is about eleven inches and that as much as 10 per cent of this may find its way to the deeper soils to maintain the ground water supply, there would be an annual supply of about 60,000 acre feet from this source. How much of this would enter the valley areas above the basaltic bed and thus be available for pumping from the lake deposits by comparatively shallow wells, is a question which only actual development of irrigation by pumping in the valley can answer.

There is an estimated area of about 1,000 square miles to the north and east of Christmas Lake Valley which slopes toward the valley and may be expected to furnish a limited supply to its underground waters. However, this area is mostly devoid of timber, and with a smaller rainfall can hardly be expected to furnish as much underground supply as the area on the slopes of the Paulina and Walker Ranges. It appears that the underground flow is generally toward Christmas Lake Valley, which is generally about 20 to 30 feet lower than Fort Rock Valley.

Assuming then, so far as underground supply is concerned, that a limited area might be served by pumping, without lowering the ground water level to any great extent, there is still the question of whether the substrata is of such character as to permit the flow of water toward wells in quantities economical for pumping.

Digitized by Google

As an example of the effect which porosity of material through which water is drawn, may have on the quantity pumped, the following comparison is made. Let it be assumed that a well of 10 inch bore is sunk 70 feet deep and the ground water level is 10 feet below the surface. A pump of 1,000 gallons per minute capacity is located at ground surface, and as 20 feet is about the limit of lift for the ordinary suction pump, the water may be lowered about 10 feet below the ground water level. If the material surrounding the well is very fine sand, it has been estimated* that the above pump will draw down the water surface in the well 10 feet in 8½ minutes; if the material is medium fine sand it will take 1½ days; and if the material is medium coarse sand the pump of 1,000 gallons per minute capacity will not be able at all to draw the water down through a depth of 10 feet by constant pumping. In other words, the material, in order to furnish a constant supply of 1,000 gallons per minute must have a porosity nearly as great as medium coarse sand, assuming in all cases that the underground supply is sufficient and the ground water is not lowered by other wells in the immediate neighborhood.

From this is seen the necessity of making thorough pumping tests, together with a careful study of the character of substrata in any locality, before the depth of well, design and capacity of pumps and motors or engines can be determined. An examination of the table, showing materials passed through in the wells and test holes (See "Wells and Domestic Supply") throughout Fort Rock and Christmas Lake valleys, shows that these materials range from sand, loose tuffaceous soil, lake silts, and sandy clay to clay, in order of porosity. With the exception of the clay, these materials are not necessarily of such low porosity as to justify the statement that wells could not be drawn from in quantities sufficient for irrigation purposes. It seems probable that the substrata in some areas might prove too impervious for practical pumping, while that under other areas would be sufficiently porous.

The following is quoted from Fleming, who has made an exhaustive study of irrigation by pumping as practiced in the United States:

"Before any decision can or should be reached with regard to the feasibility of a pumping-plant project, a careful and systematic study should be made of the matter in all its phases. This applies to the small individual plant as well as to the large central plant, perhaps with greater force to the former since such plants often represent the entire working capital of an individual who stakes his future upon the success of his venture. Ill-considered plans, wrong and costly types of machinery, too high a "pumping head," and a disregard of such simple factors as nearness to markets and suitable crops to grow with high-priced water have contributed, in the many cases which have come under the writer's observation,

*Practical Irrigation and Pumping, Fleming—1915.

Digitized by Google

to the lack of success attending a pumping-plant investment. It is not enough that there shall be cheap land and a water-bearing stratum beneath it, or some other adjacent source of water supply. This water must not be at great depth below the surface to be irrigated or the source be so far away that long pipe lines are required; otherwise it will not pay with any ordinary crop to develop the water supply, however extensive or unfailing it may be. The crop grown must in any case be one requiring relatively little water, and must give high crop value per acre, while the machinery used should be of such type as will give the service desired with a maximum of running economy and a minimum of maintenance charges."

With the uncertainties from the physical and practical standpoint in mind, as brought out in these discussions, it is thought some preliminary pumping tests should be made before any extensive outlay of capital is considered for irrigation of lands in these valleys. Briefly outlined, this might consist of sinking about four wells on one section of land, each well located to serve say 160 acres and, if finally successful, pumping equipment could be installed, followed by several months trial covering pumping from all wells. From this, a study of the effect on ground water level could be made, also of the porosity of the substrata. Should no insurmountable difficulty be found, test holes scattered over the balance of the valley should be driven, and perhaps an occasional well and equipment installed. This would serve to give extended data from which it is believed reliable conclusions might be made for a basis of further investment. The gasoline engines and pumps used in this investigation could probably be disposed of without total loss, and the wells would, at least in part, be of value for domestic service.

Assuming that the source of underground supply and porosity of substrata might prove favorable to the development of pumping over an area of about 30,000 acres in Fort Rock Valley, an estimate has been made of the cost of such development farther on in this report. However, should such development be undertaken as an extension of the proposed project, attention is called to the fact that the assumptions are made only as a basis upon which to estimate the cost of such development, and that these assumptions may not be borne out by facts.

Pumping from Ana River Springs—Summer Lake Valley.—Ana River rises in five large springs in the west half of Sec. 6, T. 30 S., R. 17 E. W. M., and flows into Summer Lake about five miles to the south. The springs are located about six miles southeast of Silver Lake. The highest spring at the head is about 40 feet above the surface of Summer Lake and about 20 feet above the lower and larger springs located about one-half mile down stream. From these springs the river flows through a narrow canyon from 30 to 50 feet deep, cut in soft, light earth of volcanic origin. The water is very clear and quite warm, varying but a few degrees from 65° Fahrenheit, and on this account is exceptionally suitable for use in irrigating. The low lands which might be irrigated by gravity, lying north and east of

Digitized by Google

Summer Lake, have in earlier times been covered by overflow from the lake, which is extremely salty. Strong westerly winds have also drifted the salt deposits for a considerable distance along the northeast side of the lake. These lands are therefore not suitable for irrigation. The only use made of the water of Ana River is for irrigating a small ranch near its mouth, and recently for the irrigation of a few hundred acres lying to the west of the canyon by a small pumping plant installed below the second spring. Various attempts have been made to dam the stream in the canyon and thus raise the water where it could be diverted over the higher adjoining lands. One such attempt failed through faulty construction, and the more recent attempt, owing to lack of financial backing, did not reach the construction stage.

Numerous gagings of Ana River, made during early surveys by the Reclamation Service, indicate an almost constant flow of 150 to 155 second feet throughout the year from the five large springs at the head of the river. The development of this supply for irrigation involves pumping the water from the canyon to canals leading out over the bench lands lying both east and west of the river.

Damming the canyon to the bench level just below the lower spring has been suggested, but the uncertainty as to whether these springs would continue their present discharge under such increased head makes the construction of such a dam inadvisable, at least for full development of flow.

Storage development at Thompson Valley in connection with the proposed Silver Lake project, and the consequent possibility of developing summer power on Silver Creek, discussed under Silver Lake bed reclamation, suggests the possibility of pumping from Ana River Springs for the irrigation of lands in Summer Lake Valley with this power.

The close proximity to each other of the springs at the head of Ana River and the even temperature of their waters point to their having a common source and underground flow, although finding their way to the surface through separate outlets. With these conditions in mind, it is not unreasonable to suppose that a dam located in the canyon below the lower springs, and raising the water about twenty feet to the elevation of the upper spring, will not materially decrease their flow.

Briefly outlined, the development proposed is as follows:

First, construction of a dam in the canyon, below the lowest spring, at a point where the stream crosses the center line of Sec. 6, T. 30 S., R. 17 E., to raise the water about 26 feet, to the elevation of the upper spring. A flume of 25 second feet capacity will carry water down the side of the canyon about one and a

Digitized by Google

half miles to its mouth, where laterals will distribute the supply to about 3,600 acres, 2,000 of which lie west of and 1,600 acres southeast of the stream. Lands lying below a line about two miles back from the northeast shore of Summer Lake have been excluded, as they are considered too alkaline.

Second, construction of a pumping station and installation of equipment on the north bank of the canyon between the third and fourth springs from the head of the river, for pumping approximately 62 second feet through a lift of 62 feet to a high line canal, and about 64 second feet through a 32 foot lift to a low line canal. The delivery to the high line canal will be through a metal flume from the pumping station to a point about 1,500 feet north, while the low line canal will originate at the station itself.

Third, construction of the low line canal from the pumping station, extending east and south a distance of about 16 miles, reducing in capacity from 60 second feet to 20 second feet, and serving 7,600 acres, lying above the gravity canal on the east side of the river; also a small lateral from the pumping station on the west side to serve about 800 acres, or a total of 8,400 acres under this low lift.

Fourth, construction of the high line canal from the end of the flume, extending east and south a distance of about 18 miles, to serve 7,500 acres lying above the low line canal on the east side of the river; also a small lateral west from the flume to serve 500 acres on the west side of the river, a total acreage under the higher lift of 8,000 acres.

Total to be served by pumping, 16,400 acres, and by gravity, 3,600 acres, or a total in the project of 20,000 acres.

The pumping plant and canals are designed to serve the land with five inches of water in July, estimating a loss in distribution of 15 per cent of water diverted and a gain to lower canals of 5 per cent of the amount diverted to higher canals during the month. This low estimated distribution loss depends on the use of not less than 10 second feet head in irrigation, and on rotation in distribution.

In the estimates of cost which follow in the latter part of this report, no allowance is made for leveling and preparing land for irrigation, although 10 per cent of the total area under canals, after deducting high areas shown on available topography, has been estimated as waste land, due to the presence of small areas of sand dunes of size probably too large for leveling at moderate cost. This deduction is believed adequate, and the remaining 90 per cent can be prepared for irrigation without undue cost. No allowance is made for drainage, though it will doubtless be required at some time in the future as the slope is generally not more than 30 feet to the mile.

Digitized by Google

No allowance is made for acquiring present rights, as no data are available for making an estimate of their value.

Climatic and soil conditions are very similar to those in Silver Lake Valley, although possibly the danger from frosts would not be quite so great in the Summer Lake region. Winter Ridge, rising 2,000 to 3,000 feet above Summer Lake on the west, forms a protection against the sweep of cold west winds over the narrow strip of land lying along the west shore of this lake. This protecting influence may be felt to some extent over the lands lying northeast of the lake, but it is believed to be slight. The strip of and along the west short is exceptionally favored in climate, as indicated by the fact that practically all vegetables and fruits for surrounding valleys are grown here. Frosts rarely occur on this side of the lake until late in the fall.

Digitized by Google

CONSTRUCTION DESIGNS AND ESTIMATES OF COST FOR COMPLETED PROJECT

SYCAN CANAL

The Sycan Canal will divert from Sycan River by means of a low masonry dam about one mile above the mouth of the canyon through which Sycan River flows until it reaches the slope above Sycan Marsh. For location of this canal see Sheet No. 39. The capacity of this canal is necessarily large on account of the high discharge of Sycan River during the spring months, when the diversion of its waters is planned. The economic capacity estimated for this canal is 300 second feet from the Sycan diversion to Chocktoot Creek, increased to 360 second feet at the Chocktoot Creek diversion, thence diminishing throughout the remainder of the canal, on account of estimated seepage losses, to about 328 second feet at the divide between Sycan Marsh and Thompson Valley. Here the canal will discharge into a stream entering Thompson Valley.

The first mile of the Sycan Canal will be along the edge of a rocky canyon and is estimated to have one side concrete lined. Typical sections showing the design may be found on Sheets Nos. 27 and 28.

Estimated Cost of Sycan Canal

Excavation,	187,830 cu. yds.	earth	@ $ .25	$46,955.00
	2,650 " "	lava rock	@ .50	1,325.00
	76,970 " "	lava rock	@ 1.25	96,210.00
Concrete	730 " "	canal lining	@ 12.00	8,760.00
Sycan diversion dam and gates				8,000.00
Wasteway and diversion structure at Chocktoot Creek				1,500.00
Culverts, 5 @ $200.00 each				1,000.00
Telephone, 12 miles @ $250.00				3,000.00
Fencing, 16 miles @ $125.00				2,000.00
Right of way, 2 miles @ $120.00				240.00
Wasteway at end of canal				1,240.00
				170,230.00
Engineering and administration, 25%				42,770.00
Total cost				$213,000.00

LONG CREEK CANAL

The location of Long Creek Canal is shown on Sheet No. 39. This canal is designed to have a capacity of 220 second feet at diversion, which it is estimated will provide for the mean high months of the years 1905 to 1915. The canal as estimated will be six miles in length and will join the Sycan diversion canal, discharging with it into Thompson Valley, at the divide mentioned. Typical sections of this canal will be found on Sheet No. 28.

Digitized by Google

Estimated Cost of Long Creek Canal

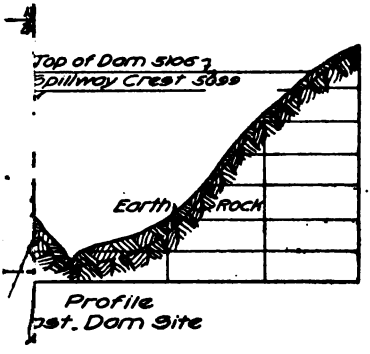
Excavation 85,400 cu. yds. earth @ 25c	$21,360.00
Diversions—Long Creek	3,000.00
Coyote Creek	1,000.00
Culverts, 2 @ $150.00	300.00
Telephone, 6 miles @ $250.00	1,500.00
Fencing, 12 miles wire fence @ $150.00	1,800.00
Right of way, 3 miles @ $120.00	360.00
	29,320.00
Engineering and administration, 25%	7,380.00
Total cost	$36,700.00

THOMPSON VALLEY RESERVOIR FOR COMPLETED PROJECT

It has been shown under "Storage Requirements" for the proposed project that the capacity required for the completed project with no provision for carry-over storage is about 54,000 acre feet. This will require the maximum elevation of water surface to be at 5,096 feet (See capacity curve, Sheet No. 22), and will flood approximately 4,000 acres. Two dams will be required—one at the East dam site and one at the West dam site. See Sheet No. 24. A low depression in the ridge between the two dam sites offers an opportunity for a comparatively cheap spillway site at an elevation of about 5,100 feet.

Preliminary estimates brought out the fact that the East and West dams can be built to an elevation of 5,106 feet, with water surface elevation at 5,099 feet, in conjunction with a spillway at this site, at as low a cost as dams three feet lower (water surface at 5,096 feet) with spillway built around the west end of the main, or East, dam. In addition there will be the decided advantage of safety in having the spillway separate from either dam. This plan will also provide greater capacity in the reservoir to the amount of 12,500 acre feet, which will be of value for carry-over storage from a year of high run-off to a year of low run-off, and probably of still more importance in holding back water in years of high run-off to make the reclamation of the bed of Silver Lake more certain. Accordingly the dams and spillway are designed in this estimate for the higher elevation. The area flooded at maximum storage is 4,500 acres. Privately owned lands to an elevation 10 feet higher than the maximum water surface elevation of 5,099 feet have been considered as subject to damage by possible wave action or ground water conditions and are included in the estimated cost of the reservoir. No drill borings were made at either dam site, and the depth below the present surface, to which cut-off walls will have to be constructed to meet a water tight strata, is uncertain.

Digitized by Google

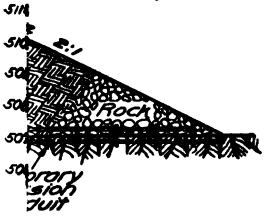


Profile
est. Dam Site

Section
Temporary Diversion
Conduit

0 5 10

Scale of Feet



Section of Spillway

0 5 10 20

Scale of Feet

OREGON COOPERATIVE WORK	
U. S. Reclamation Service and State of Oregon	
Project	SILVER LAKE
Feature	Dams - Thompson Valley Reservoir
Designed or	Date
Surveyed by	Parkhill 6-15
Drawn by	Henderson "
Traced by	"
Checked by	Ware "
Scale	Project File No. 24

Digitized by Google

Digitized by Google

From observations made at both dam sites it is not believed that any unusual difficulties will be encountered in securing a water tight bond.

East Dam.—The East Dam as planned is an earth fill type with a 3:1 slope on the reservoir side, a 2:1 slope on the down-stream face, and a 20 foot crest width. See Sheet No. 24 for plan and location of this dam. There is a rock ledge outcropping on either side of the canyon at this dam site. The outlet channel through the east end of the dam will be concrete lined, and the excavated rock placed in the down stream toe of the dam and on the riprap slope. The outlet works, consisting of a double channel with stop logs for control, is designed to pass 500 second feet with a seven foot head over the upper stop logs at any stage. Temporary diversion of Silver Creek during construction is to be taken care of by a cofferdam and temporary concrete conduit under the main body of the dam. The dam as planned is 56 feet high at the deepest section and 390 feet long at the crest line. The bottom of the outlet channel to be at the 5,065 foot contour, as the reservoir capacity below this elevation is less than 400 acre feet. Throughout the estimates for this and other dams, one cubic yard of rock in excavation is estimated to make 1.5 cubic yards of fill in embankment.

East Dam---Estimated Cost

Excavation:				
Stripping, earth and loose rock, 3,800 cu. yds.	@	$ .50	$1,900	
Outlet Channel. solid rock, 2,700 cu. yds	@	1.50	4,050	
Puddle trenches, earth, 450 cu. yds	@	.50	225	
			6,175	$ 6,175
Embankment:				
Earth from borrow, 48,155 cu. yds.	@	.60	34,890	
Rock from outlet excavation, 1,705 cu. yds.	@	.25	425	
Riprap from outlet excavation, 1,940 cu. yds.	@	.75	1,455	
			36,770	42,945
Concrete:				
Plain concrete, outlet works, 254 cu. yds.	@	18.00	4,570	
Reinforced concrete, outlet works, 200 cu. yds.	@	20.00	4.000	
Steel reinforcment outlet works, 13,375 lbs.	@	.07	940	
			9,510	52,455
Temporary Diversion				
Cofferdam			420	
Conduit—320'–28" concrete pipe	@	4.00	1,280	
Collars—20–15 cu. yds. concrete	@	20.00	300	
			2,000	54,455
Miscellaneous:				
Stop plank and hoisting devices			505	
Roads—4 miles	@	500.00	2,000	
Bridges, one, near dam			200	
Buildings, one, permanent,			2,000	
two, temporary for construction			1,000	
Drainage—excavation, labor and tiling			1,800	
			7,505	61,960
Engineering and administration, 25%				15,490
Total construction				$77,450

Digitized by Google

West Dam.—For a location and plan of this dam see Sheet No. 24. The dam is to be an earth fill type with a 3:1 slope on the reservoir side and a 2:1 slope on the downstream side. Height of dam at maximum section is 36 feet, length at crest line is 640 feet.

Temporary diversion of the Middle Fork of Silver Creek, which flows through the West dam site, will be accomplished after construction of the East or main dam by a small diversion ditch as shown on the plan on Sheet No. 24, which will take the water over a low saddle in the reservoir and discharge it into a small branch of Silver Creek. No temporary outlet works will be necessary at the West Dam as the water above this dam which would not drain over the saddle, heretofore referred to, would not exceed about 150 acre feet.

West Dam---Estimated Cost

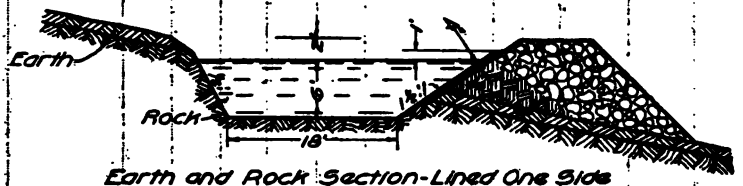
Excavation:				
Stripping, earth and loose rock, 3,040 cu. yds.	@	$ .50	$ 1,520	
Puddle trenches, earth, 910 cu. yds.	@	.50	455	
			1,975	$ 1,975
Embankment:				
Earth from borrow, 46,570 cu. yds.	@	.60	27,940	
Riprap, rock from borrow, 2130 cu. yds.	@	2.00	4,260	
			32,200	34,175
Temporary Diversion:				
Earth excavation, 390 cu. yds.	@	.30	125	
			125	34,300
Engineering and administration, 25%				8,575
Total construction				$42,875

Spillway.—The location of the spillway as planned is shown on Sheet No. 24. The spillway as designed is 100 feet wide, with crest at an elevation of 5,099 feet. The discharge capacity of this spillway with a head of 4.3 feet over the crest is 3,660 second feet, or equivalent to a discharge of 35 second feet per mile of drainage area tributary to the reservoir, estimated at 105 square miles. The discharge capacity of the spillway is 8,000 second feet, with a 7 foot head on the spillway or with water at an elevation of 5,106 feet, the level at which the East and West dams as planned would be overtopped. This is equivalent to a discharge of 76 second feet per square mile of area tributary to the reservoir. The highest discharge of record, on March 10, 1907, is estimated at 1,400 second feet at the gaging station on Silver Creek near Silver Lake. Assuming that the discharge at Thompson Valley, compared to the amount for the whole of Silver Creek watershed, is in the proportion of their drainage areas, the maximum discharge at Thompson Valley on that date would have been 930 second feet. The spillway as designed would

Digitized by Google

Sycon Diversion Canal

From Mile	Dist Miles	Elev in Feet	Functions Q	A	F	r	V	n	Description E=Earth R=Rock	Quantities Earth yds	Rock yds	Haydite Concrete yds	Concrete yds
0	095	5157.2	307	144	1055	397	2.13	025	E+R-Lined	16	48,50	17,200	—	790



Earth and Rock Section-Lined One Side
Mile 0 to Mile 0.95

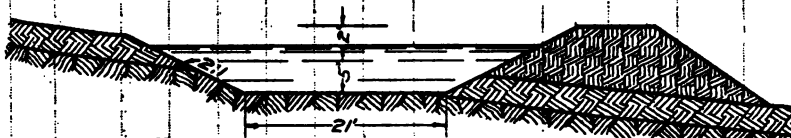
												Loose R	
095	3.13	5156.2	308	134	158	331	229	025	E+R Unlined	23,915	21,120	2,650	—

Earth and Rock Section Unlined
Mile 0.95 to Mile 4.08

4.08	2.36	5151.2	357	151	158	349	237	025	E+R Unlined	21,500	17,400	—	—
6.44	1.61	5148.2	350	160	1055	360	220	0225	Earth Unlined	30,860	—	—	—

Earth Section Unlined
Mile 6.44 to Mile 8.05

8.05	4.07	5146.2	340	155	1055	357	219	0225	E+R Unlined	75,680	13,760	—	—



Earth and Rock Section Unlined
Mile 8.05 to Mile 12.12

Explanation of Symbols for functions
"Q" is rate of flow in cu ft per second
"A" is area of water section
"F" is fall of canal in ft per mile
"r" is hydraulic radius
"V" is velocity of flow in ft per sec.
"n" is coefficient of roughness

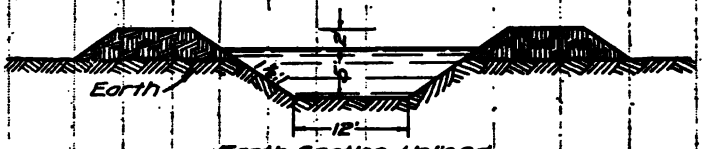
OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon

Project	SILVER LAKE	
Feature	Canal Sections	
Designed or Surveyed by	Parkhill	Date 6-15
Drawn by	Wynne	"
Traced by	Henderson	7-15
Checked by	Wynne	"
Scale	1" = 10 Feet	Project File No. 27

Digitized by Google

Digitized by Google

From Mile	Dist Miles	Elev in Feet	Functions Q	A	F	r	V	n	Description E-Earth R-Rock	Earth yds	Rock yds	Hardpan yds	Concrete yds
Sycan Diversion Canal													
1212	0.19	5142[1]	335	176	1055	4.35	1.91	.030	E+R Unlined	3970	4650	——	——
1231	1.70	5142[2]	328	150	1055	3.54	2.18	.0225	E+R Unlined	21450	2840	——	——
Long and Coyote Creek Diversion Canal													
0	6.05	5148[2]	223	97.5	1.32	3.25	2.29	.0225	Earth Unlined	85440	——	——	——



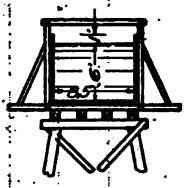
Earth Section Unlined
Mile 0 to Mile 6.05

West Canal

0	1.52	4572[2]	355	87	1.58	3.32	4.10	.014	E+R Unlined	22000	3360	——	3320
1.52	0.66	——	355	87	1.58	3.32	4.10	.014	E+R Lined	6125	4970	——	1610

Earth and Rock Section-Concrete Lined
Mile 1.52 to Mile 2.18

2.18	0.14	4568[2]	355	87	1.58	3.32	4.10	.014	E+R Unlined	855	825	——	290
2.32	0.03	4568[2]	355	51	4.75	2.40	6.92	.012	Wood Flume	——	——	——	——



Wood Flume and Trestle
Mile 2.32 to Mile 2.35

2.35	0.12		355	87	1.58	3.32	4.10	.014	E+R Lined	650	1440	——	299
2.47	0.09	4567[5]	355	87	1.58	3.32	4.10	.014	E+R Lined	875	710	——	230

Explanation of Symbols for Functions
"Q" is rate of flow in cuft per second
"A" is area of water section
"F" is fall of canal in ft. per mile
"r" is hydraulic radius
"V" is velocity of flow in ft per sec.
"n" is coefficient of roughness

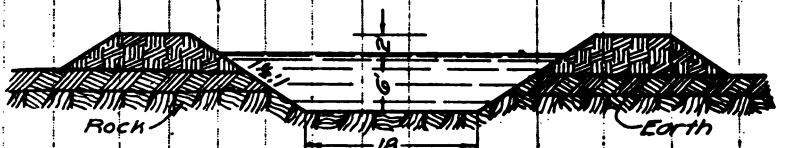
OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon

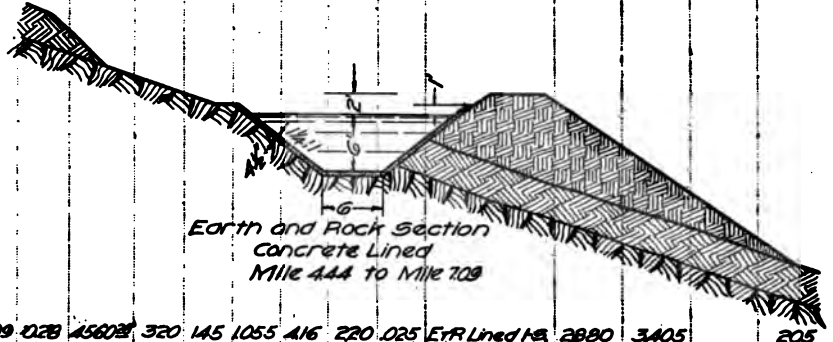
Project	SILVER LAKE	
Feature	Canal Sections	
Designed or Surveyed by	Parkhill	Date 6-15
Drawn by	Weare	"
Traced by	Henderson	7-15
Checked by	Weare	"
Scale	0 10 feet	Project File No. 28

Digitized by Google

Digitized by Google

West Canal

From Mile	Dist Miles	Elev in Feet	Functions Q	A	F	r	V	n	Description E-Earth R-Rock	Quantities Earth yds	Rock yds	Hardpan yds	Concrete yds
256	0.47		350	162	1058	4.09	2.17	.025	E+R Unlined	5000	3900	—	—
303	0.19	—	350	162	1055	4.09	2.17	.025	E+R Unlined	2050	1140	—	—
322	0.81	—	320	150	1055	3.99	2.14	.025	E+R Unlined	8170	6750	—	—
403	0.08	4566[2]	324	48	475	2.40	6.75	.012	Wood Flume	—	—	—	—
411	0.33	4565[2]	320	150	1055	3.99	2.14	.025	E+R Unlined	3465	3100	—	—
444	2.65	4564[2]	325	81	158	3.22	4.02	.014	E+R Lined	70840	17360	—	3990
709	0.28	4560[2]	320	145	1055	4.16	2.20	.025	E+R Lined 1 S.	2880	3405		205
737	0.76	—	320	150	1055	3.99	2.14	.025	E+R Unlined	7600	6280	—	—
813	0.19	4559[2]	322	72	158	3.00	4.47	.012	Wood Flume	—	1920	—	—

Earth and Rock Section Unlined
Mile 2.56 to Mile 3.03



Earth and Rock Section
Concrete Lined
Mile 4.44 to Mile 7.09

Earth and Rock Section Concrete Lined One Side
Mile 7.09 to Mile 7.37

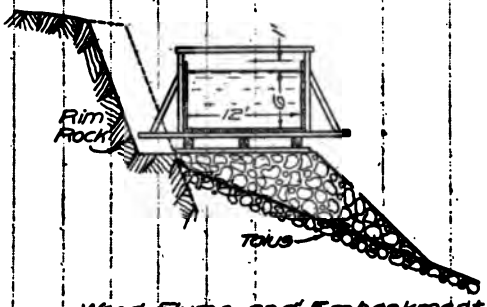
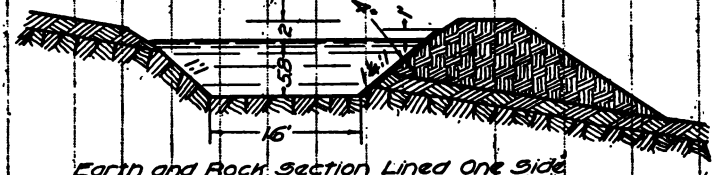
Explanation of Symbols for functions
'Q' is rate of flow in cu ft per second
'A' is area of water section
'F' is fall of canal in ft per mile
'r' is hydraulic radius
'V' is velocity of flow in ft per sec.
'n' is coefficient of roughness

OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon

Project SILVER LAKE
Feature Canal Sections
Designed or Surveyed by Parkhill — Date 6-15
Drawn by Weare — "
Traced by Henderson — 7-15
Checked by Weare — "
Scale 0 10 feet — Project File No. 29

Digitized by Google

Digitized by Google

From Mile	Dist Miles	Elev in Feet	Functions Q	A	F	r	V	n	Description E-Earth R-Rock	Quantities Earth yds	Rock yds	Hardpan yds	Concrete yds
									West Canal				
													
									Wood Flume and Embankment Mile 8.13 to Mile 8.32				
8.32	1.14	4558.64	325	81	1.58	3.22	4.02	.014	E+R Lined	30,360	7,440	—	1,710
9.46	2.46	4556.82	320	150	1.055	3.99	2.14	.025	E+R Unlined	24,700	20,410	—	—
11.92	0.19	4554.32	325	81	1.58	3.22	4.02	.014	E+R Lined	5,060	1,240	—	285
12.11	0.19	—	294.5	72	1.32	3.00	4.09	.012	Wood Flume	—	4,450	—	—
12.30	0.47	4553.62	300	143.3	1.055	3.88	2.09	.025	E+R Unlined	4,625	3,925	—	—
12.77	1.14	4553.12	300	143.3	1.055	3.88	2.09	.025	E+R Unlined	11,700	10,080	—	—
13.91	0.09	4551.82	294.5	72	1.32	3.00	4.09	.012	Wood Flume	—	910	—	—
14.00	1.14	4551.62	300	143.3	1.055	3.88	2.09	.025	E+R Unlined	11,700	10,080	—	—
15.14	1.89	4550.42	280	136.2	1.055	3.77	2.05	.025	E+R Unlined	18,000	12,500	—	—
17.03	1.51	4548.42	275	130.2	1.055	2.9	2.10	.025	E+R Lined 1:1	44,560	16,960	—	920
													
									Earth and Rock Section Lined One Side Mile 17.03 to Mile 18.54				
18.54	0.32	4546.62	265	69	1.58	2.98	3.84	.014	E+R Lined	6,072	3,377	—	617

Explanation of Symbols for Functions
"Q" is rate of flow in cu ft per second
"A" is area of water section
"F" is fall of canal in ft. per mile
"r" is hydraulic radius
"V" is velocity of flow in ft per sec.
"n" is coefficient of roughness

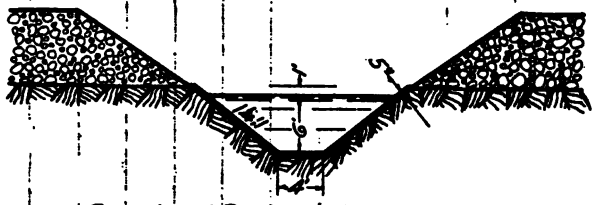
OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon

Project SILVER LAKE
Feature Canal Sections
Designed or Surveyed by Parkhill — Date 6-15
Drawn by Weare — " "
Traced by Henderson — " 7-15
Checked by Weare — " "
Scale 2 10 feet — Project File No. 30

Digitized by Google

Digitized by Google

From Mile	Dist Miles	Elev in Feet	Functions Q	A	F	r	V	n	Description E=Earth R=Rock	Quantities Earth yds	Rock yds	Hardpan yds	Concrete yds
									West Canal				
18.86	0.81	4546.4	272	123.8	1.32	3.56	2.20	.025	E+R-Unlined	8170	6321	—	—
19.67	2.08	4545.2	166	73	1.58	2.82	2.27	.0225	Earth-Unlined	22550	—	—	—
21.75	0.38	4541.3	166	73	1.58	2.82	2.27	.0225	E+R-Unlined	2600	2020	—	—
22.13	0.03	4541.5	165	52.5	5.28	1.00	3.10	.014	Earth-Lined	95	—	—	56
22.16	2.62	4526.5	166	73	1.58	2.82	2.27	.0225	E+H.Pan Unlined	21052	—	7480	—
24.78	0.47	4522.9	166	73	1.58	2.82	2.27	.0225	E+H.Pan Unlined	4350	—	1425	—
25.25	2.75	4521.8	125	56	1.85	2.5	2.24	.0225	Earth Unlined	25810	—	—	—
28.00	3.78	4516.1	69.5	34.5	2.11	1.97	2.01	.0225	Earth Unlined	23200	—	—	—
31.78	0.11	4508.1	47.3	6.9	2.64	0.85	7.88	.012	Wood Flume	—	—	—	—



Gravel and Rock Section Concrete Lined
Mile 18.54 to Mile 18.86

Earth Section Unlined
Mile 19.67 to Mile 21.75

Section Concrete Lined Chute
Mile 22.13 to Mile 22.16

Explanation of Symbols for functions
"Q" is rate of flow in cu ft per second
"A" is area of water section
"F" is fall of canal in ft per mile
"r" is hydraulic radius
"V" is velocity of flow in ft per sec.
"n" is coefficient of roughness

OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon

Project	SILVER LAKE	
Feature	Canal Sections	
Designed or Surveyed by	Parkhill	Date 6-15
Drawn by	Weare	"
Traced by	Henderson	7-15
Checked by	Weare	
Scale	0 R feet	Project File No. 31

Digitized by Google

Digitized by Google

From Mile	Dist Miles	Elev in Feet	Functions Q	A	F	r	V	n	Description E-Earth R-Rock	Quantities Earth yds	Rock yds	Handpan yds	Concrete yds
									West Canal				
									Wood Flume and Trestle Mile 3.178 to Mile 3.189				
									Silver Lake Canal				
0	0.09	4572	54	17.25	2.64	1.48	3.11	0.14	E+R Lined	275	740	—	139
									Earth and Rock Section Concrete Lined Mile 0 to Mile 0.09				
0.09	0.28	4571.35	54	28.16	2.11	1.81	1.92	0.225	E+R Unlined	615	810	—	—
									Earth and Rock Section Unlined Mile 0.09 to Mile 0.37				
0.37	1.53	4571.15	54	28.16	2.11	1.81	1.92	0.225	E+R Unlined	5920	1600	—	—
1.90	0.075	4567.85	52.8	32	4.00	0.50	1.65	0.014	24" Concrete Drop	—	—	—	26
1.975	0.725	4537.25	54	28.16	2.11	1.81	1.92	0.225	Earth Unlined	3570	—	—	—
									Earth Section Unlined Mile 1.975 to Mile 2.70				

Explanation of Symbols for functions
"Q" is rate of flow in cu ft per sec.
"A" is area of water section
"F" is fall of canal in ft. per mile
"r" is hydraulic radius
"V" is velocity of flow in ft per sec.
"n" is coefficient of roughness

OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project SILVER LAKE
Feature Canal Sections
Designed or Surveyed by Parkhill — Date 6-15
Drawn by Weare — 6-15
Traced by Henderson — 7-15
Checked by Weare — "
Scale 0 1 2 Feet — Project File No. 32

Digitized by Google

Digitized by Google

From Mile	Dist Miles	Elev in Feet	Functions Q	A	F	r	V	n	Description E-Earth R-Rock	Quantities Earth yds	Rock yds	Manipan yds	Concrete yds
			Silver Lake Canal										
2.70	1.20	4536.43	42	22.5	2625	1.63	1.98	.0225	Earth Unlined	5800	—	—	—

Earth Section Unlined
Mile 2.70 to Mile 3.90

3.90	1.60	4533.83	20	10	4.78	1.09	2.00	.0225	Earth Unlined	3140	—	—	—

Earth Section Unlined
Mile 3.90 to Mile 5.50

5.50	.050	4525.83	20	3.1	1.08	0.50	6.4	.014	24" Concrete Crossing	—	—	—	32.4
5.58	0.86	4520.33	20	10	4.70	1.09	2.00	.0225	Earth Unlined	1665	—	—	—
6.44	0.10	4506.18	20	1.77	2.70	3.77	11.3	.013	18" Concrete Drop	—	—	—	27.8
6.54	1.22	4489.18	20	10	4.72	1.09	2.00	.0225	Earth Unlined	2370	—	—	—

Explanation of Symbols for Functions
"Q" is rate of flow in cu ft per second
"A" is area of water section
"F" is fall of canal in ft. per mile
"r" is hydraulic radius
"V" is velocity of flow in ft per sec.
"n" is coefficient of roughness

OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon

Project SILVER LAKE
Feature CANAL Sections
Designed or Surveyed by Parkhill — Date 6-15
Drawn by Ware — " —
Traced by Henderson — Date 7-15
Checked by Ware — " —
Scale 0 10 Feet. Project File No. 33

Digitized by Google

Digitized by Google

thus take care of nearly nine times that flood discharge, starting with the reservoir full, and neglecting also to include the water which the reservoir would contain in raising the water surface from the spillway crest to the 5,106 foot elevation, or 7 feet over the entire surface of the reservoir.

Spillway---Estimated Cost

Excavation:				
Earth, 100 cu. yds.	@	$ .50	$ 50	
Rock, trench for weir, 20 cu. yds.	@	1.50	30	
Concrete, 36 cu. yds.	@	20.00	720	
			800	
Engineering and administration, 25%			200	
Total construction			$1,000	

Estimated Cost Thompson Valley Reservoir and Lands

Lands:				
680 acres pasture and partly improved land	@	$25	$17,000	
2,400 acres unimproved lands	@	$10	24,000	
			41,000	$41,000
3,000 acres unpatented lands				00
Roads, 6 miles wagon road	@	$1,000		6,000
Bridges, 1 highway bridge	@	500		500
Clearing, 400 acres	@	10		4,000
Purchasing, legal and administration				4,900
Total cost				$56,400

Total Cost Thompson Valley Storage for Completed Project

East Dam—Total Construction Cost	77,450
West Dam— " " "	42,875
Spillway — " " "	1,000
Reservoir —Lands, roads, clearing, etc	56,400
Total Cost to Project	$177,725

The net amount estimated to be available from Thompson Valley storage in a mean year is 48,100 acre feet. At the above cost of $177,725 this would amount to a cost of $3.70 per acre foot available for use.

A detailed study of available supply from the reservoir as planned, with capacity for hold-over storage, has been made from 1904 to the present date. In addition to the 4,000 acre feet, estimated storage requirements for the 8,000 acres of Paulina Marsh lands having partial rights, it is estimated that these lands would be benefitted on account of the hold-over storage and the regulation of the stream flow in the spring months, to an extent equivalent to the furnishing of 400 acre feet annually.

Accordingly in this estimate of cost of the proposed project, the 8,000 acres of Paulina Marsh lands will be charged with their share of Thompson Valley storage costs to the amount of 4,400 acre feet at $3.70 per acre foot, which is in round numbers $16,000.

Digitized by Google

SILVER CREEK DIVERSION DAM

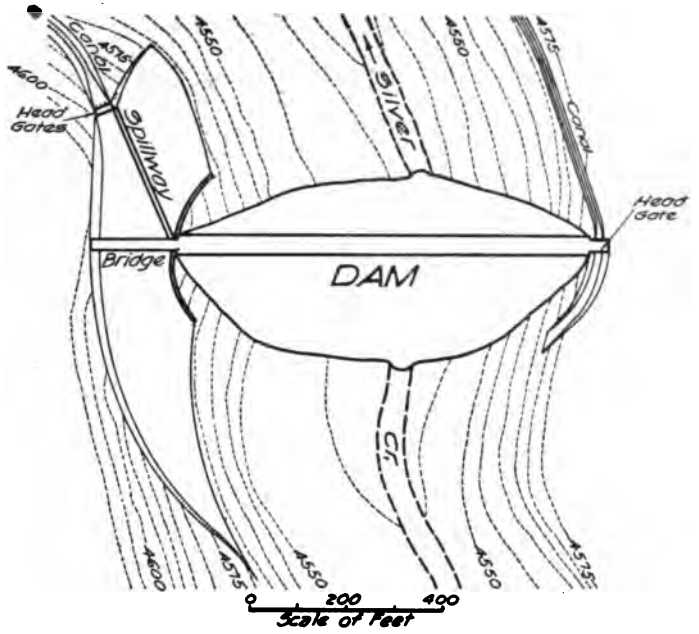
The Silver Creek diversion dam will be located a short distance above the mouth of the canyon through which Silver Creek enters the Egli reservoir site. See Sheet No. 26. For plan and section of the dam see Sheet No. 25. The dam as planned will be of the earth and rock fill type with a 3:1 slope on the upstream side, 1½:1 slope on the downstream side, and a 20 foot crest width. The rock fill in the lower part of the dam is to be made from the spillway excavation around the north end of the dam. The spillway is designed to discharge 6,000 second feet, with a 5 foot head on the spillway crest or 2 feet below the stage at which the dam would be overtopped. Length of dam at top is 420 feet between the spillway at north end and gate structures for Silver Lake Canal at the south end. Height of dam at maximum section is 44 feet. No drill borings were made at this site, but both banks of the canyon are of lava rock with boulders and earth on the lower slope.

The West Canal will divert from the spillway channel at the north end of the dam with its headgates at the outer end of the spillway crest. The Silver Lake Canal will divert around the south end of the dam as shown on Sheet No. 25.

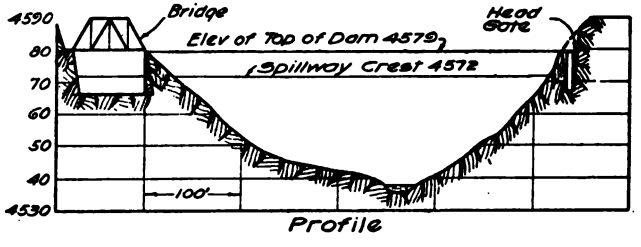
Silver Creek Diversion Dam—Estimated Cost

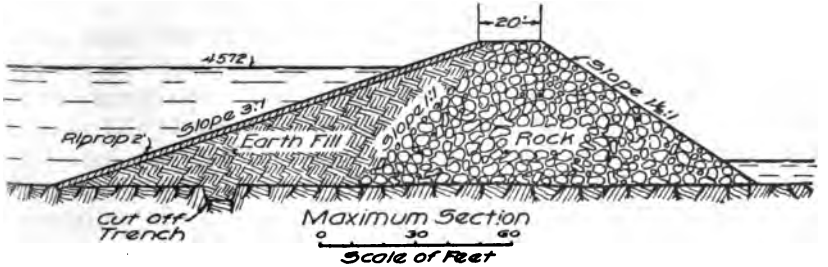
Excavation:		
Stripping earth and loose rock, 2,000 cu. yds. @ 50¢	$ 1,000	
Cut-off trenches, rock, 1,800 cu. yds. @ $1.50	2,700	
Diversion, south bank, rock, 1,000 cu. yds. @ $1.50	1,500	
Spillway, north bank, rock, 18,000 cu. yds. @ $1.25	22,500	
	27,700	$27,700
Embankment:		
Earth fill from borrow, 14,215 cu. yds. @ 60¢	8,530	
Cut-off trenches, earth from borrow, 1,800 cu. yds. @ 60¢	1,080	
Rock fill, from spillway excavation, 24,515 cu. yds. @ 25¢	6,130	
Riprap, rock from spillway excavation, 2,000 cu. yds. @ 75¢	1,500	
	17,240	44,940
Concrete:		
Spillway retaining walls, 125 cu. yds. @ $15	1,875	
Steel retaining walls, 2,450 lbs. @ 7¢	170	
	2,045	46,985
Temporary Diversion:		
Temporary diversion dam	175	
Flume, 1,350 feet long @ $1.50	2,025	
	2,200	49,185
Miscellaneous:		
Diversion gate, including structures for West Canal $850, Silver Lake Canal $400	1,250	
Buildings, one permanent	500	
Drainage, excavation labor and tiling	1,000	
	2,750	51,935
Engineering and administration, 25%		12,965
Total cost		$64,900

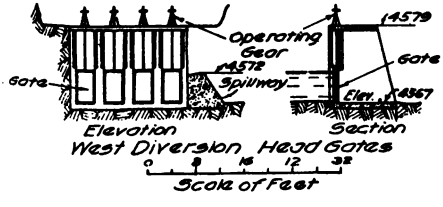
Digitized by Google



SILVER CREEK DIVERSION DAM







OREGON COOPERATIVE WORK		
U. S. Reclamation Service and State of Oregon		
Project	SILVER LAKE	
Feature	Silver Creek Diversion Dam	
Designed or Surveyed by		Date
Drawn by	Weare	6-15
Traced by	Henderson	"
Checked by	Parkhill	"
Scale		Project File No. 25

Digitized by Google

Digitized by Google

COST PER ACRE FOOT AT DIVERSION

The supply available for diversion at the Silver Creek diversion dam, assuming no losses in Silver Creek between the Thompson Valley reservoir and this dam, has been estimated to be 62,500 acre feet.

Following is a tabulation of the costs of the features necessary to obtain this diversion:

Sycan Canal	$213,000
Long Creek Canal	36,700
Thompson Valley Reservoir	177,725
Silver Creek Diversion Dam and Gates	64,900
Total cost including diversion	$492,325

Cost per acre foot diverted, $7.88.

DISTRIBUTING SYSTEM

The distributing system for the completed project will consist of two diversion canals, diverting one from either end of Silver Creek diversion dam (See Sheet No. 34), with the distributing laterals required to serve the different units coming under these two canals. The Silver Lake canal, with a capacity of 55 second feet at diversion, will serve 7,500 acres of irrigable land lying between Silver Creek and Silver Lake, here called Silver Lake Unit. The West Canal, with a capacity at diversion of 350 second feet, will serve three units: Paulina Unit, consisting of 9,000 acres of irrigable land lying on the western slope of Paulina Marsh from Silver Creek north to the Conley Hills; Fort Rock Unit, in the vicinity of Fort Rock, consisting of 21,300 acres of irrigable land; and Horning Bend Unit, consisting of 10,800 acres of irrigable land lying along the northern and eastern slopes of Conley Hills. The last named unit will be served by the Horning Bend lateral, diverting from the West Canal near the twenty-mile point and having a capacity at diversion of 90 second feet. The total irrigable acreage estimated in the three units under the West Canal and Horning Bend lateral, is 41,000 acres. The canals shown on Sheet No. 34 constitute that part of the canal system on which actual estimates have been made. For construction designs and estimates of quantities of excavation in these canals, see Sheets Nos. 27 to 33 inclusive. The classification of material in these estimates is based partly on test holes made with a post auger during canal surveys, and in part on surface examination. The estimated cost of excavation in earth has been taken at 25 cents per cubic yard in main canals, to include possible excavation in hardpan, where occurrence of this could not be determined from surface examination. In like manner, the cost of excavation in the lateral system under the Silver Lake Unit has been taken at 22 cents per cubic yard, as these laterals are comparatively shallow.

Digitized by Google

A detailed estimate was made of the cost of small laterals, turnouts, checks, measuring weirs, etc., required to distribute water from the Silver Lake Canal to each 40 acre tract in the Silver Lake Unit, as will be shown in the estimate of cost of the distributing system for the Silver Lake Unit. Separate estimates for 1,000 acres and 3,000 acres respectively of the Silver Lake Unit were made and reduced to cost per acre for distribution. These figures, together with that for cost of distributing per acre for the entire Silver Lake Unit, give the cost of distribution to three units of varying size, from which a scale of cost, depending on the number of thousands of acres in a unit, has been estimated. This scale has been applied on the different sized units of land occuring under the West Canal as tabulated below.

Probable Cost of Distributing to Units of Varying Sizes.
(Excavation all earth. including 10 per cent hardpan.)
(All structures of wood.)

Size of Units, in acres.	Distributing Cost per Acre.	
	From actual estimate.	Estimated scale.
1,000	$2.36	$2.30
2,000	....	2.75
3,000	3.09	3.10
4,000	....	3.40
5,000	....	3.65
6,000	....	3.90
7,500	4.22*	4.21
8,000	....	4.35
9,000	....	4.50
10,000	....	4.70
12,000	....	5.05
13,400	....	5.25

*Estimated cost of distribution to Silver Lake unit, including that portion of the main canal lying within the unit.

Silver Lake Canal and Distributing System.—The Silver Lake Canal will divert from the south end of the Silver Lake diversion dam with a capacity of about 55 second feet. The first 500 feet of this canal is along steep canyon side, and is designed to be concrete lined for this distance. From this point, the canal is of ordinary earth section, unlined, and reduces in capacity to about 40 second feet at the end of the first four miles. The total length of canal is about 7.7 miles with a capacity of 20 second feet at the end. For location of this canal and the Silver Lake Unit see Sheet No. 34. Typical section and estimates of quantity in this canal are shown on Sheets No. 32 and 33.

Digitized by Google

Estimated Cost of Silver Lake Canal

Excavation			
Earth and hardpan,	23,350 cu. yds. @ $ .25	$5,840	
Rock	3,150 " " @ 1.25	3,940	
			$ 9,780
Concrete canal lining	139 " " @ 11.00	1,530	1,530
Concrete pipe line drops and siphon 400 feet 24" reinforced concrete pipe	@ 2.50	1,000	
2 end structures for above	@ 50.00	100	
500 feet 24" reinforced concrete pipe	@ 2.50	1,250	
2 end structures for above	@ 50.00	100	
600 feet 18" concrete pipe	@ 1.50	900	
2 end structures for above	@ 50.00	100	
			3,450
Miscellaneous			
Wasteways	1	500	
Highway bridges,	2 @ $100	200	
Culverts	3 " 100	300	
Fencing	4 miles @ $125	500	
Right of way	2 " " 250	500	
Telephone line	8 " " 250	2,000	
			4,000
Engineering, administration and contengencies,			18,760
25%			4,690
Total construction			$23,450

Estimated Cost of Distributing System—Silver Lake

Laterals			
44 miles, 10 second foot capacity, 58,075 cu. yds @ 22¢		12,780	
1-¾ miles, 20 second foot capacity, 3,680 cu. yds. @ 22¢		$ 810	
			$13,590
Main canal turnouts			
3-10 second foot, without checks, @ $30		90	
1-20 second foot, with check in main canal		100	
			190
Lateral Structures			
Turnouts, without checks, 37 @ $15.20		564	
" with " 61 " 35.00		2,135	
Drops, in 10 second foot lateral, 219 @ $20.00		4,380	
" " 20 " " " 18 @ 27.00		486	
Measuring weirs,	61 @ 25.00	1,525	
Bridges, 8 over 10 second foot laterals, @ $21.00		170	
			9,260
			23,040
Engineering and Administration, 25%			5,760
Total distribution cost exclusive of Silver Lake Canal			$28,800

Digitized by Google

Total Estimated Cost of Silver Lake Canal and Distributing System.

Silver Lake Canal, total construction cost	$23,450
Distribution system, Silver Lake Unit	28,800
Total construction cost	$52,250

West Canal and Distributing System.—The West Canal will divert from the north end of the Silver Creek diversion dam and run northwest for about ten miles, the greater portion of the way along the steep side of a rimrock bluff. Within the first five miles will come the Bridge Creek and Buck Creek crossings. The estimates for these crossings provide for wood flume on trestles (See Sheets Nos. 28 to 32 inclusive). Within this first ten mile section estimates provide for about seven miles of concrete lined canal and six-tenths of a mile of wood flume. The total length of the West Canal is about 32 miles, and 24.4 miles of this is to be of the ordinary earth section type. The capacity of the West Canal is as follows:

At diversion .....350 sec. ft.
At Buck Creek crossing .....320 " "
At junction with the Horning Bend lateral....265 " "

Diminishing from that point to about 40 second feet at the end of the canal, as estimated. The canal losses provided for are taken at one inch in depth over the wetted area per twenty-four hours in lined section, and one foot in depth per twenty-four hours over the wetted area of earth sections, with the exception of the Horning Bend lateral and the West Canal from the Horning Bend lateral to about the 28-mile point. Test holes along the West Canal indicated in this section rather coarse gravel underneath the soil, and it is believed that canal losses there will be greater. In this case a loss of one and one-half feet in depth over the wetted area per twenty-four hours has been allowed.

Digitized by Google

West Canal—Estimated Cost

Excavation			
Earth,	365,114 cu. yds. @ $ .25	$ 91,280	
Rock	154,973 " " " 1.25	193,715	
Hardpan,	8,905 " " " .50	4,450	
			$289,445
Concrete			
Canal lining, 1¼ to 1 side slopes, 13,476 cu. yds. @ 11.00		148,236	
Structure concrete, 56 cu. yds. @ 11.00		614	
			148,850
Flumes			
Bridge Creek crossing—150 feet,			
Lumber, 21,600 ft. B. M. @ $40 M. erected		864	
Footings, excavation and hardware		336	
			1,200
Buck Creek crossing—450 feet,			
Lumber, 74,000 ft. B. M. @ $40 M. erected		2,960	
Footings, excavation and hardware		540	
			3,500
End West Canal—600 feet,			
Lumber, 30,000 ft. B. M. @ $40 M. erected		1,200	
Footings, excavation and hardware		300	
			1,500
Bench Flumes,			
1,000 feet—Mile 8.13 to 8.32			
1,000 " — " 12.11 " 12.30			
500 " — " 13.91 " 14.00			
2,500 " —110 ft. B. M. per foot @ $40 M. erected			11,000
Special structures			
Lumber, hardware, riprap, etc. for end structures of concrete chute—Mile 22.13 to 22.16		125	
Concrete pipe line drop at Mile 28		2,500	
			2,625
Turnouts, not included in distribution,			
Main Canal turnouts, 1—90 s. f. @ $150		150	
2 50 " @ 100		200	
3 20 " @ 60		180	
2 10 " @ 50		100	
2 15 " @ 40		80	
			710
Miscellaneous			
Wasteways, 4 main canal @ $500		2,000	
Bridges, 8 " " @ 100		800	
Fencing, " " 30 mi. @ 125		3,750	
Right of way		5,020	
Telephone, 30 " @ 250		7,500	
			19,070
			477,900
Engineering, administration and contingencies, 25%			119,100
Total construction			$597,000

Digitized by Google

Horning Bend Lateral—Estimated Cost

Excavation				
Earth ,83,140 cu. yds. @ $ .25				$20,785
Concrete				
Pipe line drop, 700 ft. 30" pipe @ $3.00			$2,100	
End structures for above, 2 @ 50.00			100	
				2,200
Turnouts not included in distribution				
1—20 s. f. from 90 s. f.			40	
1—40 " " 70 "			45	
				85
Miscellaneous				
Wasteways,	2	@ $250.00	500	
Fencing,	20 miles	@ 125.00	2,500	
Bridges,	4	@ 50.00	200	
Right of way			730	
Telephone,	20 miles	@ 250.00	5,000	
				8,930
				32,000
Engineering, administration and contingencies, 25%				8,000
Total construction				$40,000

Estimated Cost of Distributing System

Paulina Unit:				
1,000 acres,	Silver Cr. to Bridge Cr. @ $2.30		$2,300	
3,000 "	Bridge Cr. to Buck Cr. @ 3.10		9,300	
2,000 "	Mi. 7 to mi. 13, W. Canal @ 2.75		5,500	
1,000 "	" 13 " " 16, " " @ 2.30		2,300	
2,000 "	North of Paulina Marsh @ 2.75		5,500	
9,000				$24,900
Horning Bend Unit:				
2,000 acres,	0 to 5 mi. Horning Bend Lateral @ 2.75		5,500	
4,000 "	5 to 12 mi. Horning Bend Lateral @ 3.40		13,600	
4,800 "	12 mi. to end, Horning Bend Lateral @ 3.60		17,300	
10,800				36,400
Fort Rock Unit:				
5,600 acres,	mi. 20 to Fort Rock @ 3.80		21,280	
13,400 "	Fort Rock north @ 5.25		70,350	
2,300 "	end of canal west @ 2.85		6,550	
21,300				98,180
				159,480
Engineering, administration and contingencies, 25%				39,870
Total construction cost, 41,100 acres				$199,350

Estimated Cost of West Canal and Distributing System

West Canal—Total construction cost	$597,000
Horning Bend Lateral—Total construction cost	40,000
Distributing system—Paulina, Horning Bend and Fort Rock Units	199,350
Total cost West Canal and Distributing System	836,350

Cost per acre, $20.35.

Digitized by Google

Total Construction Cost of Gravity Project Completed

Sycan Canal		$213,000
Long Creek Canal		36,700
Thompson Valley Storage*		177,725
Silver Creek Diversion Dam		64,900
Silver Lake Canal and Distribution System		52,250
West Canal and Distribution System		836,350
		1,380,925
*Storage for 8,000 acres Pauline Marsh @ $2.00	$ 16,000	
48600 acres gravity project composed	1,364,925	
		$1,380,925

Estimated cost per acre, $28.08.

*See under "Total Cost Thompson Valley storage for Completed Project."

Digitized by Google

CONSTRUCTION DESIGNS AND ESTIMATES OF COST FOR DEVELOPMENT BY STAGES.

FIRST STAGE DEVELOPMENT—SILVER LAKE UNIT.

The first stage development involves the use of the waters of upper Silver Creek only, by providing storage at Thompson Valley for the winter and early spring run-off, and calls for the irrigation of the Silver Lake Unit of 7,500 acres. The storage required in this stage development will be less than that for the completed project, since it is not planned to divert waters from the Sycan drainage basin. It is proposed to furnish 4,000 acre feet of water from the Thompson Valley storage annually to the 8,000 acres of Paulina Marsh in addition to the normal flow of lower Silver Creek. The features required for this stage of development are: Thompson Valley storage, Silver Creek diversion dam, Silver Creek canal and distribution to Silver Lake Unit.

The advantages of this development as proposed are that the water supply does not involve conflicting interests, other than those of about 8,000 acres of Paulina Marsh lands which it is proposed to provide for in the design for storage at Thompson Valley. Also the distributing system for the Silver Lake Unit from the Silver Creek diversion dam is independent of those units to be served by the West Canal and is identically the same as planned for the completed project.

Thompson Valley Reservoir for First Stage Development.—Under "Existing Water Rights and Supply Available for Other Lands" it has been estimated that there is available in a mean year about 19,100 acre feet from Silver Creek at Thompson Valley. Reservoir losses during a year for this inflow were estimated at 2,800 acre feet by seepage, and 3,300 acre feet by evaporation. Taking the seepage loss during the storage period at two-thirds, and the evaporation loss during this time at one-half the yearly amount, there is a total seepage and evaporation loss of about 3,500 acre feet. Under these conditions the storage capacity required is 15,600 acre feet.

Storage at Thompson Valley for this capacity would require a maximum water surface at 5,083 feet elevation. The comparatively low cost of storage at Thompson Valley and the fluctuation of the run-off from year to year, as indicated by records of flow, make it seem advisable to provide for hold-over storage. With this in view the storage planned for the first stage development is about 25,000 acre feet, with the maximum water surface elevation in the reservoir at 5,087 feet, and the top of the East Dam at an elevation of 5,094 feet.

East Dam.—The scheme as proposed is to provide the outlet works as planned for the completed project but to carry the embankment in the East Dam only to the 5,094 foot elevation. The

Digitized by Google

dam at maximum section will be 44 feet high and have a length at crest line of 320 feet. The embankment is planned with a 3:1 slope on the reservoir side and a 2:1 slope on the downstream face, with a crest 20 feet in width. This embankment would be so placed with reference to the outlet works that the dam could be raised by widening on the downstream slope and carrying the crest width to the proper elevation for the dam, as planned for the proposed completed project.

East Dam—Estimated Cost for First Stage Development.

Excavation:		
Stripping, earth and loose rock, 1,600 cu. yds. @ 50¢	$ 800	
Outlet channel, rock, 2,700 cu. yds. @ $1.50	4,050	
Puddle trenches, earth, 330 cu. yds. @ 50¢	165	
	5,015	$ 5,015
Embankment:		
Earth from borrow, 36,530 cu. yds. @ 60¢	21,920	
Rock from outlet channel, 1,860 cu. yds. @ 25¢	465	
Riprap from outlet channel, 1,740 cu. yds. @ 75¢	1,305	
	23,690	28,705
Concrete:		
Plain concrete in outlet works, 254 cu. yds. @ $18	4,570	
Reinforced concrete in outlet works, 200 cu. yds. @ $20	4,000	
Steel reinforcement, outlet works, 13,375 lbs. @ 7¢	940	
	9,510	38,215
Temporary Diversion:		
Cofferdam	420	
300'–28" concrete pipe @ $4	1,200	
18 concrete collars, 14 cu. yds. @ $20	280	
	1,900	40,115
Miscellaneous:		
Stop Planks and hoisting devices	505	
Roads, 4 miles @ $500	2,000	
Bridges, 1 near dam @ $200	200	
Buildings, 1 permanent	2,000	
" 2 temporary for construction @ $500	$1,000	
Drainage—Excavation, labor and tiling	1,000	
	6,705	46,820
Engineering and administration, 25%		11,780
Total Cost		$58,600

West Dam and Spillway.—The West Dam and spillway as planned for this stage development is not located at the West dam site. See Sheet No. 24.

Near the center of Section 19, T. 30 S., R. 14 E., is a low saddle, dividing that portion of the reservoir basin which drains through the West dam site from the portion draining into Silver Creek and through the East dam site. The elevation of this saddle at the low point is 5,085 feet.

The plan here proposed is to build a low dyke or dam across this saddle having a maximum height of about 8 feet. The length at crest line is 3,850 feet, with a spillway near the north

Digitized by Google

end of the dyke. This embankment will have a 3:1 slope on the reservoir side, a 1½:1 slope on the back, and 10 foot crest width. The embankment will be of earth taken from either side. The spillway as planned is 180 feet wide, with rubble masonry retaining walls and combined rubble masonry and concrete weir. It will discharge 4,000 second feet, with a flood crest of 3.2 feet over the spillway ,which is an equivalent discharge of 38 second feet per square mile of the area tributary to the reservoir.

The spillway with flood crest reaching top of dyke, at an elevation of 5,093 feet, or with 5 feet head on the spillway crest, will discharge approximately 8,000 second feet.

West Dam (Dyke) and Spillway—Estimated Cost for First Stage Development.

Excavation:			
Puddle trench, earth, 2,130 cu. yds. @ $ .30		$ 640	
Spillway, rock 50 " " @ 1.50		75	
" earth 80 " " @ .30		25	
		740	$ 740
Embankment:			
Earth from borrow, 19,415 cu. yds. @ 30¢		5,825	
Riprap, rock from borrow, 3,610 cu. yds. @ $2.15		7,760	
		13,585	14,325
Spillway:			
Cut-off and retaining walls, rubble masonry, 48 cu. yds. @ $10		480	
Spillway weir, rubble masonry, 135 cu. yds. @ $10		1,350	
Plain concrete, 45 cu. yds. @ $18		810	
		2,640	16,965
Miscellaneous:			
Preparing foundation, ploughing and rolling, 3 acres @ $20		60	
Diversion of Middle Fork to reservoir		125	
		185	17,150
Engineering and administration, 25%			4,250
Total cost			$21,400

Estimated Cost of Thompson Valley Reservoir and Lands for First Stage Development.

Lands:		
680 acres, pasture and partly improved lands, @ $25	$17,000	
2,080 acres unimproved lands, @ $10	20,800	
	$37,800	$37,800
3,000 acres unpatented lands		00
Roads, 6 miles wagon road @ $1,000		6,000
Bridges, 1 highway bridge @ $500		500
Clearing, 400 acres @ $10		4,000
Purchasing, legal and administration		4,900
Total Reservoir Cost		$53,200

Digitized by Google

Estimated Cost of Thompson Valley Storage for First Stage Development.

East Dam, construction cost	$58,600
West Dam (dyke) and spillway construction cost	21,400
Reservoir lands, roads, bridges, etc.	53,200
Total storage cost	$133,200

The supply available from storage at Thompson Valley as planned above, with assumptions as to seepage and evaporation losses (See "Existing Water Rights and Supply Available for Other Lands"), is 13,000 acre feet, and the cost per acre foot stored is $10.25.

Estimated Cost of First Stage Development—Silver Lake Unit.—Under "Total Estimated Cost for Thompson Valley Storage for the Completed Project," it has been shown that the 8,000 acres of Paulina Marsh hay lands should stand a proportional part of the cost of Thompson Valley storage to the amount of $16,000. This was estimated on the basis of the final development of Thompson Valley storage. The same figures are used in the following summary.

Total Cost and Cost per Acre of First Stage Development—Silver Lake Unit.

Thompson Valley storage for First Stage Development		$133,200
Silver Creek diversion dam and gates		64,900
Silver Lake Canal and distributing system (Silver Lake Unit)		52,250
		$250,350
Storage for 8,000 acres Paulina Marsh @ $2.00	$16,000	
Total cost to 7,500 acres Silver Lake Unit	234,350	
		$250,350

Estimated cost per acre, $31.25.

SECOND STAGE DEVELOPMENT—PAULINA UNIT.

Second stage development as outlined under "Proposed Stages of Development" requires building that part of the West Canal necessary to reach all of the Paulina Unit, and involves procuring an increased water supply by building the Long Creek diversion canal. It has been shown that the supply thus acquired would be sufficient for the Paulina Unit without additional storage at Thompson Valley. The second stage development provides, as in the first stage development, for the additional storage required by the 8,000 acres of Paulina Marsh lands to the extent of 4,000 acre feet annually; for the irrigation of Silver Lake Unit, 7,500 acres; and in addition for the irrigation of the Paulina Unit, 9,000 acres, a total of 16,300 acres of new lands.

The second stage development as proposed is offered only as an intermediate step between the development of the Silver Lake Unit and the final development of the completed project. The plan proposed contemplates building the first 17 miles of the

Digitized by Google

West Canal to the capacity required for the completed project. This makes the acre cost of the second stage development excessive, as will be seen in the estimates following. A portion of the cost of constructing the West Canal for this stage development should be borne by the Horning Bend and Fort Rock Units.

West Canal for Second Stage Development.—The West Canal will be built as designed for the completed project to mile 17.03 (See Sheets Nos. 28, 29 and 30).

Estimated Cost of West Canal for Second Stage Development—Mile 0 to Mile 17.03.

Excavation:		
Earth, 236,655 cu. yds. @ $ .25	$ 59,160	
Rock 126,295 " " @ 1.25	157,870	
		$217,030
Concrete:		
Canal lining, 11,939 cu. yds. @ $11		131,330
Flumes:		
Bridge Creek Crossing	1,200	
Buck Creek Crossing	3,500	
Bench flumes, 2,500 feet	11,000	
		15,700
Turnouts, not included in distribution:		
Main Canal turnouts, 3-20 s. f. @ $60	180	
2-15 " @ $50	100	
2-10 " @ $40	80	
		360
Miscellaneous:		
Wasteways. 1 main canal	500	
Bridges, 3 main canal @ $100	300	
Fencing, 17 miles @ $125	2,130	
Right of way	2,500	
Telephone line, 15 miles @ $250	3,750	
		9,180
		373,600
Engineering, administration and contingencies 25%		93,400
Total construction cost		$467,000

Estimated Cost of Second Stage Development.

Long Creek Canal—total construction cost		$ 36,700
West Canal, mi. 0 to mi. 17.03—total construction cost		467,000
Distributing system—Paulina Unit	$24,900	
Engineering, administration and contingencies, 25%	6,200	
		31,100
Total estimated cost, second stage development		$534,800

Estimated Cost of First and Second Stage Development.

Estimated cost of first stage development, Silver Lake Unit	$250,350
Estimated cost of second stage development, Paulina Unit	534,800
Total estimated cost first and second stage developments	$785,150

Digitized by Google

THIRD STAGE DEVELOPMENT—PROJECT COMPLETED.

The third stage development, by which the project as outlined under "Proposed Project," would be completed, includes completion of Thompson Valley storage, construction of the Sycan diversion canal and extending the West Canal from mile 17.03 to the end, together with the Horning Bend lateral and distributing systems required for the Horning Bend and Fort Rock Units.

Thompson Valley Reservoir for Third Stage Development.—The plan proposed is to complete the Thompson Valley reservoir from the first stage development, to make it identical as to capacity of reservoir, height of dams, spillway and maximum water surface, with the plans for the Thompson Valley reservoir as proposed under "Completed Project" heretofore described. This is to be brought about by completion of the East Dam, building of a new West Dam and a new spillway, the two latter to be identical with those planned for the completed project. See Sheet No. 24.

The estimated cost of the West Dam would probably be somewhat reduced because earth and riprap can be secured at a lower cost from the embankment in the low West Dam to be discarded, than from borrow, as would be required in case the dam were built at the outset for the completed project. No temporary diversion dam will be required for the middle fork of Silver Creek, as the estimates for the first stage development covered the cost of diverting the waters of this stream into the reservoir.

Completion of East Dam. —The construction of the East dam, as planned for first stage development, provides for the excavation of the outlet channel and construction of the outlet works for final development. The estimate for the completion of the East dam does not, therefore, include any cost for this work. The completion of the East dam will require only the raising of the dam twelve feet from the crest level of 5,094 feet to 5,106 feet, and the necessary widening on the downstream face to keep the same slopes, 3 to 1 and 2 to 1, with a 20 foot crest width at the top. It will be necessary, in addition, to riprap the reservoir slope above the former top level to the top of the completed dam.

Digitized by Google

Completion of East Dam—Estimated Cost.

Excavation:		
Stripping below toe of dam and at ends, 1,400 cu. yds. @ $ .50		$ 700
Embankment:		
Earth, 20,890 cu. yds. @ $ .60	$12,534	
780 " " riprap @ $2.00	1,560	
		14,094
		14,794
Engineering, administration and contingencies, 25%		3,696
Total cost, completion of East Dam		$18,490

West Dam—Estimated Cost.

Excavation:					
Stripping, earth,	3,040 cu. yds.	@	$0.50	$ 1,520	
Puddle trenches, earth	910 " "	@	0.50	455	
					$1,975
Embankment:					
Earth from borrow,	27,570 cu. yds.	@	0.60	16,540	
" " low West dam	19,000 " "	@	0.50	9,500	
Riprap from low West dam	2,130 " "	@	1.00	2,130	
					28,170
					30,145
Engineering, administration and contingencies, 25%					7,535
Total construction cost					$37,680

Estimated Cost of Completing Thompson Valley Reservoir.—By comparing the estimates of the cost of the Thompson Valley reservoir lands for the completed project and for the first stage development it will be seen that the only difference is in the acreage of privately owned unimproved lands to the extent of 320 acres. These will have to be acquired for the final development, and estimating that their value may increase $5 per acre, or from $10 to $15 per acre, the cost for completed reservoir will be 320 acres at $15, or $4,800.

Estimated Cost of Completing Thompson Valley Reservoir.

Completion of East Dam, total construction cost	$18,490
West Dam at West dam site, total construction cost	37,680
Spillway, identical with that for completed project	1,000
Purchase of additional reservoir lands	4,800
Total cost of completing reservoir	$61,970

Completion of West Canal and Distributing System.—Under the plan of development by stages, the West Canal to mile 17.03, and distributing system for the Paulina Unit will be completed during the second stage development; final development will be completion of the West Canal and the Horning Bend lateral, and the distributing systems under these extensions. For the purpose of this estimate the cost of this completion will be

Digitized by Google

taken as the difference between the cost of the West Canal and distributing system for the completed project and of the West Canal to mile 17.03 and distributing system for the Paulina Unit as estimated for the second stage development. The latter cost briefly stated is as follows:

West Canal, mile 0 to mile 17.03		$467,000
Distributing system, Paulina Unit		31,100
Total		$498,100

Estimated Cost of Third Stage Development.

Completion of Thompson Valley reservoir and dams		$ 61,970
Sycan diversion canal—total construction cost		213,000
West Canal and distributing system for completed project—total estimated cost	$836,350	
West Canal to mile 17.03 and Paulina Unit distributing system (2nd stage development)	498,100	
Completion of West Canal and distributing system		338,250
Total construction cost—third stage development		613,220

Total Cost of Gravity Project Completed by Stages.

First Stage development—Silver Lake Unit		$ 250,350
Second " " —Paulina Unit		534,800
Third " " —Horning Bend and Fort Rock Units		613,220
Total cost gravity project completed		$1,398,370
Cost to 8,000 acres for storage	$ 16,000	
Cost to 48,600 acres gravity project	1,382,370	
		$1,398,370

Cost per acre $28.45.

Comparison of Cost of Gravity Project Completed in One Stage and in Three Stages.—In order to make any comparison of the cost of the project to be completed in one stage with the cost if completed in a number of stages, it will be necessary to assume some length of time between the stages of development, and some rate or rates of interest on the invested principal. For the purpose of this discussion, let it be assumed that it will take three years for the construction of the project, completed in one stage, one year of construction for each stage of development if completed in three stages, and that five years will intervene between each two stages of development. Then, considering rates of interest from 3 per cent to 6 per cent, the following tabulation will give a comparison of costs at the time the project would be completed if constructed by stages, under the assumptions as to time of development requiring a total period of twelve years. The interest is compounded.

Digitized by Google

Stage.	Principal Invested.	R—Rate of Interest. T—Time in Years.								
		R.	T.	Amount.	R.	T.	Amount.	R.	T.	Amount.
1st.....	$ 250,350	3%	12	$ 357,000	5%	12	$ 449,630	6%	12	$ 503,700
2nd.....	534,800	3%	6	638,500	5%	6	716,600	6%	6	758,880
2rd.....	613,220	3%	0	613,220	5%	0	613,220	6%	0	613,220
Total..	$1,398,370	....	....	$1,608,720	....	....	$1,779,450	....	....	$1,875,800
One stage	1,380,925	3%	11	1,911,300	5%	11	2,361,510	6%	11	2,621,000
Amount in favor of construction by stages.....				$ 302,580			$ 582,060			$ 745,200

The excess cost of development of the project in the three stages proposed over the cost of development in one stage is entirely in the development of the Thompson Valley storage in two stages, as shown below.

Cost of development of completed project in three stages	$1,398,370	
Cost of development of completed project in one stage	1,380,925	
Additional cost of development by three stages		$17,445
Cost of Thompson Valley storage for first stage development	$133,200	
Cost of completing Thompson Valley storage for third stage development	61,970	
Total cost Thompson Valley storage completed in two stages	195,170	
Cost of Thompson Valley storage if completed in one stage	177,725	
Additional cost of development of storage in two stages		$17,445

This tabulation appears to furnish an argument against the development of the Thompson Valley storage in two stages. The argument in favor of this development is that records of flow of Silver Creek kept at Thompson Valley and at the gaging station near Silver Lake for a year or part of a year would give more reliable data on which the storage requirements at Thompson Valley for the first stage development proposed could be determined at once, while the storage requirement for water diverted from Sycan Marsh drainage could not be determined to any degree of certainty without stream flow data from the tributaries entering Sycan Marsh for several years at least, and the uncertainty of being able to secure these waters to any considerable extent on account of conflicting interests which might arise. The securing of the data for determining the flow of these streams and the adjustments of the rights thereon would come as a natural step before undertaking the second and third stage developments proposed, and these considerations have been taken into account in proposing the smaller capacity reservoir at Thompson Valley for the first stage development.

Digitized by Google

CONSTRUCTION DESIGNS AND ESTIMATES OF COST FOR POSSIBLE EXTENSIONS.

PAULINA MARSH RECLAMATION.

Under "Possible Extension," the reclamation of Paulina Marsh has been outlined briefly. The diversion canals estimated for this scheme are of the same general type as the earth canal sections for the proposed project, with 1½ to 1 side slopes. These canals, located below the somewhat rocky slopes above the marsh, would require very little if any rock excavation. The drainage canals are designed with 1½ to 1 side slopes, and generally with the water surface for the estimated maximum carrying capacity required, at from 2 to 3 feet feet below the surrounding ground level, in order to provide drainage for lands immediately adjacent to them.

Emory Reservoir.—The Emory reservoir on Buck Creek for the estimated capacity required, 12,000 acre feet (See "Water Supply, Paulina Marsh Reclamation"), requires the construction of one dam at the Emory dam site (See Sheet No. 23) and the spillway about 1,000 feet southeast of the dam site, through a saddle over which the road from the reservoir site to Silver Lake passes.

Records show that of the 585 acres lying in the reservoir site, 370 acres are patented, 150 acres are under homestead entry, and 65 acres are unpatented. In the estimates of cost to follow, it will be assumed that all 40 acre tracts, part of which would be submerged under the proposed storage, will require to be purchased. An allowance is made for re-constructing the present Silver Lake—Klamath County road above the reservoir surface as planned .

Emory Dam.—See Sheet No. 35 for plan and location. The proposed dam is of the earth fill type, with a 3 to 1 slope on the reservoir side, a 2 to 1 slope on the downstream side, and a 20 foot crest width. Rock from the outlet channel and spillway is to be used to riprap the reservoir slope of the dam, the balance to be placed in the toe of the dam. Length of dam at top is 320 feet; height of maximum section 70 feet; bottom of outlet works at 4,600 feet elevation, as the reservoir capacity below this elevation is only about 300 acre feet. Temporary diversion during construction is to be accomplished by a diversion dam, just above the crossing of the 4,600 foot contour with the Buck Creek channel in the reservoir, and a ditch of about 8 second feet capacity, to carry the low summer flow to the outlet channel during construction period. This outlet channel will be excavated before the embankment is made.

The outlet works as planned provide for a discharge of 90 second feet through a single 4½ foot opening between piers

Digitized by Google

grooved for heavy stop planks. The design is practically the same as for the outlet works of the proposed East Dam at Thompson Valley (See Sheet No. 24), except that there will be a single opening instead of a double opening as in the case of the East Dam.

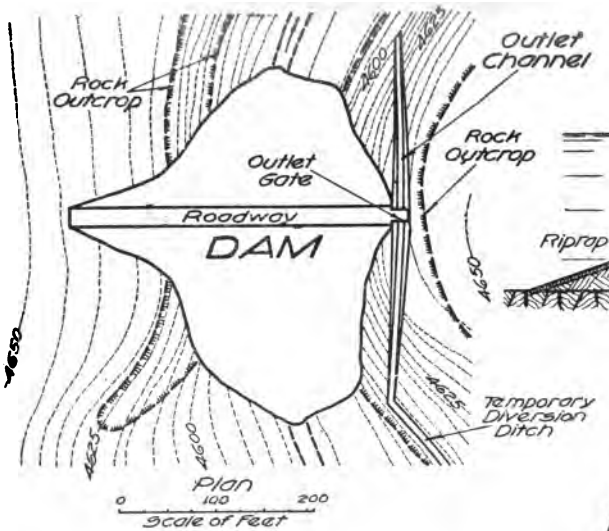
Emory Dam—Estimated Cost.

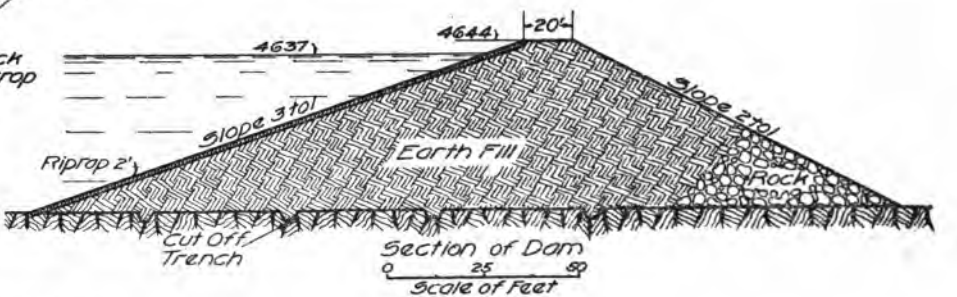
Excavation:					
Stripping earth and loose rock,	1,200	cu. yds.	@	$0.50	$ 600
Cut-off trenches, rock	1,500	cu. yds.	@	1.50	2,250
Outlet channel, rock	6,540	cu. yds.	@	1.50	9,810
					$12,660
Embankment:					
Earth fill from spillway,	3,230	cu. yds.	@	$0.40	1,292
Earth fill from borrow,	51,443	cu. yds.	@	0.60	30,866
Rock fill from outlet channel,	8,380	cu. yds.	@	0.25	2,095
Rock fill from spillway,	4,106	cu. yds.	@	0.40	1,642
Riprap from outlet channel,	2,140	cu. yds.	@	0.75	1,605
					37,500
Concrete:					
Outlet works, concrete,	158	cu. yds.	@	20.00	3,160
" " steel,	10,680	lbs.	@	0.07	750
					3,910
Temporary Diversion:					
Small cofferdam (Elev. 4,602 ft.)					200
8-sec. ft. canal, 1 mile,	1,760	cu. yds.	@	$0.50	880
					1,080
Miscellaneous:					
Stop planks and lifting devices					500
Buildings, permanant, one					1,000
temporary construction, two @ $250					500
Drainage, excavation, labor and tiling					1,000
					3,000
					58,150
Engineering, administration and contingencies, 25%					14,550
Total construction cost					$72,700

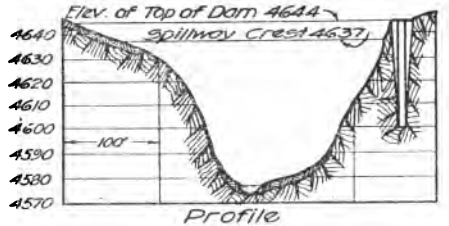
Spillway.—The spillway as designed, with a width of 80 feet, has an estimated discharge capacity of 3,740 second feet, with the water surface in the reservoir five feet above the spillway crest, or two feet below the top of the dam as planned. Before the dam would be overtopped, the spillway will discharge 6,440 second feet, and since the maximum recorded discharge of Buck Creek is 390 second feet, there seems to be a liberal factor of safety. For location and section of spillway, see Sheet No. 35.

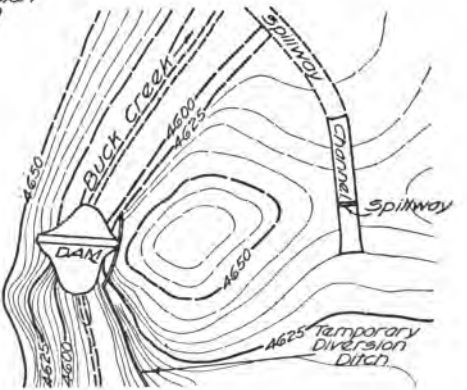
Digitized by Google

BUCK CREEK DAM









Dam and Spillway Locations
0 400 800
Scale of Feet

OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon

Project	SILVER LAKE	
Feature	Buck Cr Dam & Spillway - Emery Site	
Designed or		Date
Surveyed by	Parkhill - Weare	7-15
Drawn by	Henderson	"
Traced by	"	"
Checked by	Parkhill	"
Scale	Project File No.	35

Digitized by Google

Digitized by Google

Spillway—Estimated Cost.

Excavation:			
Earth,	3,600 cu. yds. @ $0.25	$ 900	
Rock,	3,080 " " @ 1.50	4,620	
			$5,520
Concrete:			
Spillway weir,	28 cu. yds. @ $18.00		500
			6,020
Engineering, administration and contingencies, 25%			1,500
Total construction cost			$7,520

Emory Reservoir—Estimated Cost.

Emory Dam—total construction cost			$72,700
Spillway — " " "			7,520
Reservoir lands, roads, etc.:			
Patented lands, improved,	200 acres @ $40	$8,000	
" " unimproved,	480 " @ 10	4,800	
Unpatented lands,	200 " @ 00	00	
Road, reconstructed, 2 miles @ $1,000		2,000	
Bridge, one		1,000	
Telephone line, 2½ miles @ $250		625	
Purchasing, legal and administration		1,575	
			18,000
Total cost—Emory Reservoir			$98,220

Cost of Water per Acre Foot at Diversion.—It has been estimated that the yearly supply available from Buck Creek under the proposed plan of storage is 14,000 acre feet, and the cost of storage $98,220, a cost at diversion of $7.00 per acre foot.

Distributing System.—The cost of the distributing system for the Paulina Marsh lands, from the canals to the farms, will be taken in this estimate at the same cost per acre as corresponding sized units in the proposed main project. While there will be no drop structures required, due to the very slight slope of the lands, the cross-sectional areas of distributing laterals will in many cases have to be larger than for corresponding laterals in the Silver Lake Unit on this account. Accordingly it is thought the cost of the increased yardage in excavation in the laterals will be compensated, to a large extent, by the absence of drop structures. The unit price taken for excavation in canals and laterals is 20 cents per cubic yard, as it is not thought that hardpan would be encountered to any extent in either canals or laterals.

Digitized by Google

Estimated Cost of Canals and Distributing System—Paulina Marsh.

Diversions:			
Upper diversion and gates (wood structures)		$1,000	
Lower " " " " "		2,000	
			$ 3,000
Canals:			
Excavation			
From upper to lower diversion, 4 miles, 28,400 cu. yds. earth @ $0.20		5,680	
North Branch canal, 9 miles, 49,300 cu. yds. earth @ $0.20		9,860	
South Branch canal, 2½ miles, 9,860 cu. yds. earth @ $0.20		1,970	
			17,510
Distributing laterals, turnouts—structures:			
Upper to lower diversion, 2,500 acres @ $3.00		7,500	
North Branch Canal, 4,100 " @ 3.50		14,350	
South " " 2,500 " @ 3.00		7,500	
			29,350
Miscellaneous:			
Highway bridges over canals, 4 @ $100		400	
Fencing, 20 mi. @ 125		2,500	
Right of way and damages		5,000	
Telephone lines, 10 mi. @ 250		2,500	
			10,400
			60,260
Engineering, administration and contingencies, 25%			15,040
Total estimated distributing cost			$75,300

Paulina Marsh Drainage.—Under the proposed plan for Paulina Marsh drainage, a canal will be required from the lower diversion point on Buck Creek to Silver Lake, a distance of 10¾ miles. The capacity estimated to be required in this drainage canal increases from 30 second feet at the lower diversion point to 120 second feet at the entrance to Silver Lake. The last five miles of this canal, in addition to draining the north end of Paulina Marsh, will drain about 4,000 acres of land for which storage is provided in the proposed Silver Lake Project. Consequently these latter lands should bear a proportional part of the cost of the main drainage canal, and deduction for this will be made in estimating the cost of drainage for the 9,100 acres under consideration.

Digitized by Google

Drainage Canal—Estimated Cost.

Excavation:			
Mile 0 to mile 2,	17,740 cu. yds. @ $0.20	$ 3,540	
" 2 " " 4,	38,300 " " @ .20	7,660	
" 4 " " 6,	48,800 " " @ .20	9,760	
" 6 " end,	126,200 " " @ .20	25,240	
			$46,200
Miscellaneous:			
Highway Bridges,	1 @ $100	100	
Fencing	20 miles @ 125	2,500	
Right of way and damages		5,000	
			7,600
			53,800
Engineering, administration and contingencies, 25%			13,400
Total estimated construction cost			$67,200
9,100 acres @ $5.13		$46,680	
4,000 " @ 5.13		20,520	
			$67,200

Cost of Paulina Marsh Reclamation.—To the above cost for drainage canals should be added the cost for branch drainage channels, intake structures, etc., which for the purposes of this estimate will be taken at $1.00 per acre.

Estimated Cost of Paulina Marsh Reclamation.

Buck Creek Storage—Emory Reservoir	$98,220
Distributing canals, laterals, structures	75,300
Drainage canals (9,100 acres @ 5.13)	46,680
Drainage laterals, tiling, etc. (9,100 acres @ $1.)	9,100
Total	$229,300

Estimated cost per acre $25.20.

ESTIMATES OF COST FOR SILVER LAKE RECLAMATION.

The estimates of cost for this feature are based on the assumption that the Silver Lake gravity project and the Paulina Marsh reclamation will be completed prior to undertaking the reclamation of the bed of Silver Lake. It is quite probable that the railroad lines now under construction in Eastern Oregon, whose location surveys extend through the Christmas Lake and Fort Rock valleys, will be in operation by the time this latter reclamation is taken up. Hence transportation will reach to within twelve miles of the lake (See Sheet No. 19), and unit prices affected by freight charges have been reduced from those used in the previous estimates.

It has been considered that the excavation for that part of the dyke extending from the deepest part of the lake to the east end, where the pumping plant will be located, will make the required drainage channel, on the reservoir side, to conduct the drainage from Paulina Marsh to the pumping plant, after the

Digitized by Google

reservoir supply is exhausted; also the excavation for the dyke will form a channel on the south side of the dyke to conduct drainage from the 6,500 acres of reclaimed land to the pumping plant where it will be pumped up for re-use or discharge into the Thorn Lake channel.

Estimated Cost of Power.—There is a total drop in Silver Creek of approximately 530 feet in about twelve miles of the stream, from outlet of the proposed Thompson Valley reservoir to the Egli Reservoir site. There is thus seen the possibility of developing about 27,500 theoretical horse power on this stream through the months of May, June and July, when about 450 second feet would be turned down Silver Creek from Thompson Valley storage under the proposed development of the completed Silver Lake Project. An estimate has been made for the development of about 2,400 horse power, generator output, just below the east dam at Thompson Valley, where about 4,000 feet of flume from the outlet works of the east dam conducted down the canyon side would give a head of 120 feet. The estimated cost per horse power of generator output, taking advantage of the east dam for diversion, is $87.50. This estimate was made in connection with a study of the possibility of reclaiming the bed of Silver Lake and of pumping from wells for irrigating lands on the Fort Rock desert not served by the proposed gravity project. See "Estimated Cost of Power" under "Estimated Cost of Pumping to Additional Lands in Fort Rock Valley." The uncertainty of being able to pump a sufficient supply from shallow wells for irrigation of lands in Fort Rock Valley makes it desirable to estimate an independent power plant for the reclamation of Silver Lake, which will require about 200 horse power at the pump motors.

A site located on lower Silver Creek would require only about 11 miles of transmission line as against 15 miles from the East dam site. The desirability of being able to utilize power for pumping drainage water from the reclaimed bed, from early spring to late fall, possibly two months before the irrigating season opens and three months after the season closes, makes the location of a power site on lower Silver Creek more desirable for this reclamation, as the water used would not have to be taken from storage at Thompson Valley except during the irrigating season, and then only in connection with the irrigation use for which it is reserved.

The Silver Creek diversion dam, at the upper end of the Egli reservoir site, offers an advantage in that the water is raised about 40 feet above the creek bed. The enlargement of the Silver Lake canal to 150 second feet capacity, from the south end of the dam for a distance of about 1,000 feet below it, to conduct water to a power house located at the south end of the Egli site,

Digitized by Google

will make possible the development of a 48 foot head. By reference to Sheet No. 36 it will be seen that there is estimated to be available from lower Silver Creek in a mean year about 20 second feet on March first, increasing to about 80, second feet in early April. This supply will be increased to 100 second feet in the latter part of April, from Thompson Valley storage, for irrigating the 8,000 acres of Paulina Marsh north of the Silver Lake Unit. This flow of 100 second feet will be available to pass through the penstocks of the power house until about June 10, when the supply will be gradually diminished to about 30 second feet during August, to conform to the variation in irrigation needs of the lands mentioned. It will thus be seen that with a 48 foot fall, power to a maximum of about 100 second feet can be delevoped at this site, without conflicting with irrigation uses. This maximum would last about two months, and permit the development of 540 theoretical horse power, which with an efficiency of 75 per cent in the power plant would give 400 horse power generator output. As already stated, the power estimated to be required during the months of high use at the pumping plant is 200 horse power. With an efficiency of 90 per cent in transmission line and transformers, 225 horse power will be required from the power station. Thus the possible 400 horse power need not all be developed.

Beginning in September there will be available a flow of about 10 second feet during the fall months, which is estimated capable of pumping about 15 second feet against a lift of 12 feet at the pumping station for keeping the reclaimed lands drained after the irrigation season closes, should the seepage from the reservoir to the reclaimed lands prove excessive.

It is estimated that the cost of power development at the Egli site, with the advantage of the Silver Creek diversion dam already constructed, will be about $100 per horse power, or $22,500 for the 225 horse power required.

Estimated Cost of Pumping.—The cost of pumping will be estimated as a first construction cost for necessary power and pumping plants, and a yearly cost, including depreciation, maintenance and operation, as follows:

Digitized by Google

Estimated Cost of Pumping.

Pumping Plant:				
Building and foundations for pump units			$1,880	
3-25 second foot motor driven pump units	@	$3,186	9,560	
3-75 K. W. transformers, erected	@	690	2,070	
Switch boards 150 K. W., erected	@	4	600	
Draft and discharge tubes and excavation			1,290	
				$15,400
Power Plant, 225 horse power @ $100				22,500
Transmission Line, 11 miles @ 800				8,800
				46,700
Engineering, administration and contingencies, 25%				11,675
Total construction cost				$58,375

Estimated cost of construction per acre, $8.98.

The yearly cost of operating the pumping plant is estimated as follows:

1 Superintendent	12 mos.	@	$150	$1,800
1 Assistant, pumping plant	8 "	@	125	1,000
1 " " "	6 "	@	100	600
1 " power "	6 "	@	100	600
1 Lineman, transmission line	2 "	@	100	200
				$4,200

Feature.	Depreciation.		Maintenance.		Operation.	Total.
	Rate.	Amount.	Rate.	Amount.		
Power Plant.....	5%	$1,125	1%	$225	$2,000	$3,350
Transmission Line...	8%	705	1%	90	200	995
Pumping Plant.....	5%	770	1%	155	2,000	2,925
Total.....	.....	$2,600	.....	$470	$4,200	$7,270

Estimated yearly pumping cost per acre, $1.12.

Digitized by Google

Estimated Cost of Silver Lake Reclamation.

Dyke across Silver Lake:		
Earth embankment, 107,000 cu. yds. @ $0.20	$21,400	
Rock riprap 5,380 " " @ 1.50	8,000	
		$29,400
Overflow channel to Thorn Lake:		
Earth excavation, 90,440 cu. yds. @ $0.15	13,560	
Highway bridge	200	
Right of way and damages	2,000	
Head gates	540	
		16,300
Main Canal, 9 miles:		
Earth excavation, 55,000 cu. yds. @ $ .20	11,000	
Rock " 2,550 " " @ 1.50	3,825	
Turnouts—Main Canal, 10 @ 50.00	500	
Culverts " " 4 @ 100.00	400	
Head gates	475	
		16,200
Distributing laterals and structures, 6,500 acres @ $2.50		16,250
Drainage laterals, 6,500 acres @ $1.50		9,750
Telephone line—9 miles @ $250		2,250
Fencing—18 miles @ $125		2,250
Total exclusive of pumping		$92,400
Power Plant, 225 generator horse power @ $100		22,500
Power transmission line, 11 miles @ $800		8,800
Pumping plant		15,400
		139,100
Engineering, administration and contingencies, 25%		34,800
Total construction cost for 6,500 acres		$173,900
Estimated construction cost per acre $26.75.		

Probable Cost per Acre of Reclaiming Silver Lake Bed.—It has been estimated as above that the construction cost for reclaiming the 6,500 acres of the bed of Silver Lake is about $26.75 per acre. In addition to maintaining and operating the reservoir, outlet channel, main canal and distributing system, features which have to be provided for in any gravity project, there will be the yearly expense of maintaining and operating the pumping feature. This has been estimated to cost $1.12 per acre per year.

In order to make a fair comparison between the cost of reclaiming this part of the bed of Silver Lake and the cost of the gravity project proposed, it will be necessary to capitalize this yearly operation and maintenance cost of $1.12 per acre and add this to the construction cost per acre. The rate of interest to be considered for this purpose will vary in different parts of the country and from year to year, but as it affects directly the irrigator who has to pay this yearly cost, it should be considered as that average rate which the irrigator might expect to get on money invested from time to time. This will probably vary from 5 per cent invested in bonds to 10 or 12 per cent invested

Digitized by Google

in bank stock or first mortgages. It will therefore be taken at 8 per cent for purposes of this discussion. $1.12 per year capitalized at 8 per cent amounts to a capital of $14.00. This amount added to the estimated construction cost of $26.75 makes the acre cost of the reclamation of Silver Lake bed about $40.75, as compared with $28.06, the acre cost estimated for the proposed Silver Lake Project.

ESTIMATED COST OF PUMPING TO ADDITIONAL LANDS IN FORT ROCK VALLEY.

It should be distinctly noted that the assumptions made as to underground water supply and porosity of the substrata are only partly warranted by conditions known to exist, and that the development outlined, and on which this estimate is based, should be preceded by actual pumping tests.

It is assumed that seasonal requirements under careful use of water will be 12 inches, and that the use in June will be 37 per cent, or about 4½ inches. Allowing for a 10 per cent loss in distributing to 160 acre tracts, the pumping duty during the high month will be 5 inches. The total pumping head estimated is made up as follows:

Average depth to ground water level	20 feet
Draw down allowed under maximum pumping	10 "
Friction in pipes and valves	3 "
Total pumping head	33 "

The power required for the assumed area of 30,000 acres will depend on the design and capacity of the small pumping units. The capacity best adapted to these pump units depends on a great many conditions which cannot be foreseen until some units have been installed and the results studied. One of these conditions is the amount of water which may be pumped from a well in any given locality without drawing down the ground water level beyond, say, 10 or 15 feet.

A great many firms of excellent standing manufacture and carry in stock centrifugal pumps, varying in capacity from 20 to 5,000 gallons per minute under heads varying from 5 to 100 feet. Thorough working tests have been made, and curves platted for the common sizes in use show an efficiency varying from 40 per cent in the small pumps to as high as 75 per cent in those of 2,000 gallons per minute capacity or over. A study of these efficiencies of pumps and of motors seems to indicate that with proper selection, sizes of suction and discharge pipes, and motors, to suit conditions for moderate lift, efficiencies may be expected ranging from 50 to 60 per cent in pump units, directly connected to motors, varying in capacity from 500 to 2,000 gal-

Digitized by Google

lons per minute respectively. The larger capacity units are undoubtedly more economical from the standpoint of power consumed.

Another question directly affecting the capacity of the pump unit is the head desired for irrigation. Late practice throughout the irrigated districts of the west points toward the use of heads of as much as 10 second feet as being more economical, both in the amount of water required (there being less waste with higher heads) and in the cost of labor in irrigating. In the proposed project the smallest lateral for distributing has been estimated at 10 second feet capacity. However, for pumping it is not thought practicable to provide for such a head from individual pumping units, but this should be at least 5 second feet, even at the expense of providing storage if the pumping unit is of smaller capacity. The following is quoted from Fleming's discussion* on reservoirs for pump units:

"It seldom requires more than one season's experience with a pumping plant to convince the operator or owner that a reservoir in connection with an individual plant is an eminently desirable, if not necessary, adjunct. The pumping plant, which will operate day in and day out through the entire season without some serious difficulty arising, has not yet been built, and these difficulties, frequently causing a shut-down for several days or a week at a time, quite invariably occur when the crop is in most need of water. A shut-down at such a time, particularly with garden crops or melons, may mean the loss of the crop and it is highly important, therefore, that there be some reserve supply of water against such emergencies. There are also other arguments in favor of the reservoir, among which is the fact that by means of a reservoir it is possible to make use of a greater 'head' of water when irrigating than is yielded by the pumping plant, since the discharge of the pump for several hours may be retained by the reservoir and then rapidly drawn off through a good-sized ditch to the point of use. By so doing, it is possible to cover a larger amount of land with the same quantity of water than would be possible with a small stream, a fact which every practical irrigator recognizes. Moreover, by the use of a reservoir, it is possible to irrigate profitably a much larger area with a small plant than would otherwise be possible, since the plant may pump water into the reservoir in the night-time and in intervals between irrigations, reducing in this way the stand-by expenses or length of time during the year that the large plant would be idle, and during which time interest charges on the plant and depreciation keep accumulating the same as though it were in operation. A reservoir suitable for the purpose should not be an expensive piece of work, particularly in a region where clay or adobe soils may be encountered."

The large pumping unit is probably the best, where the porosity of the substrata will permit of the rapid drawing of water from a well, is more economical from the standpoint of power consumed, and does away with the necessity of a storage reservoir. A substrata more impervious may necessitate smaller pumping units and a small reservoir, for storing water pumped during the night and for obtaining a suitable head while irrigating.

*Practical Irrigation and Pumping, Fleming—1915.

Digitized by Google

Two units covering these conditions will be estimated. It has been estimated (See "Artesian Supply") that Mr. Eickemeyer's well near Fort Rock, the only one tested in the valley, will discharge about 600 gallons per minute for at least four hours, the longest test made. This well, the first 35 feet of which are through sand and gravel, may possibly be made to yield as high as 1,000 gallons per minute, but it is probably more favorably located to produce a good flow than the average well in this valley ,as indicated in the tabulation shown under "Wells and Domestic Supply."

If the average well could be made to produce 500 gallons per minute, which is not at all certain, two wells connected to one pump might yield 1,000 gallons per minute, which is desirable to serve 160 acres. It will require the constant pumping of 500 gallons per minute to serve 160 acres with 5 inches of water during June. Estimating that for various reasons, such as unavoidable absence of the irrigator and necessity of shut-downs for repairs, the plant will not operate more than 15 days per month, it is thought advisable to provide a plant of double this capacity. The smaller unit is therefore designed for 1,000 gallons per minute, and a reservoir of 2.2 acre feet is provided, which will hold about 12 hours pumping. With the reservoir full and the pump supplying 1,000 gallons per minute, a head of 5 second feet could be used for 9.6 hours before emptying the reservoir. The larger unit as estimated, serving 320 acres, provides for a 2,000 gallon pump connected to four wells, to furnish a head of 4.5 second feet without storage reservoir.

Power Required for 30,000 acres.

Units.	Pumping lift feet.	Gals. per min.	Acres to serve	Theoretical horsepower required.	Estimated Unit Efficiency.	Actual unit horsepower required.	Number of units.	Actual horsepower delivered to pumps 30,000 acres.
Small Units...	33	1000	160	8.3	55%	15.0	188	2,820
Large Units...	33	2000	320	16.6	60%	27.6	94	2,595

The plan as estimated provides for a power plant on Silver Creek about 4,000 feet below the east dam site for the proposed Thompson Valley reservoir, 45 miles of main power transmission line, 4 substations and transformers, and 210 miles of distributing power lines. Assuming the following efficiencies, power station transformers, 98 per cent; main transmission lines, 95 per cent; substation transformers, 98 per cent; and distributing power lines, 95 per cent, the efficiency of the distributing system as a whole is estimated at 87 per cent, and the power required

Digitized by Google

at the power station generators for the 30,000 acres is 3,240 horse power for the small units and 2,985 horse power for the larger units.

Estimated Cost of Power.—The possibility of developing power on Silver Creek, following storage for the proposed project at Thompson Valley, has been discussed under "Estimates of Cost for Silver Lake Reclamation." The power plant was designed to have a capacity of 2,400 horse power generator output, to provide power for the reclamation of the bed of Silver Lake as well as for pumping to additional lands in Fort Rock Valley. Following is the estimate for power development for 2,400 horse power generator output:

Estimated Cost of Power Plant.

Generating station and equipment:		
3-800 H. P. units including power house, tailrace, wheels, generators, transformers, @ $60 H. P.	$144,000	
Land and cottage for Superintendent	1,500	
" " " " 2 operators @ $1,000	2,000	
		$147,500
Flume—4,000 feet, 310 second feet capacity		
Lumber, 570,000 feet B. M. @ $22 erected	12,540	
Clearing and right of way	1,000	
Footings, 800 @ $1.25	1,000	
		14,540
Forebay, estimated		4,000
Penstocks, 3-100 second feet capacity, each 300 feet long @ $160 per foot	1,440	
Anchorages—3 @ $100	300	
		1,740
		167,780
Engineering, administration and contingencies, 25%		42,220
Total construction cost		$210,000

Estimated cost per H. P. generator output, $87.50.

The above estimate is on the basis of 2,400 H. P. generator output. It is thought the cost of a larger plant to supply the 3,240 and 2,985 H. P. required for the small and large unit plans respectively, would be about $85 per H. P. generator output, or $275,400 for the small unit plan and $253,800 for the larger.

Estimated Cost of Pumping.—The cost of pumping will be shown as a first construction cost of power plant and distributing system down to the individual farm units, and the yearly cost necessary to maintain and operate these features.

Digitized by Google

Estimated Cost of Pumping to 30,000 Acres.

Transmission lines:		
30 miles (wood pole) main line @ $2,000	$60,000	
15 " " " spur lines @ 1,500	22,500	
		$82,500
Distributing System:		
Substations—including building, transformers, switchboard and cottage for operator		
2 substations, 570 K. W. capacity @ $8,930 each	17,860	
1 " 650 K. W. "	9,560	
1 " 270 K. W. "	6,180	
		33,600
Distributing Power Lines:		
210 miles @ $800		168,000
		284,100
Engineering, administration and contingencies, 25%		70,900
		355,000
Power Plant—3,240 H. P. @ $85—total construction cost		275,400
Total construction cost—power features only		630,400

Estimated cost per acre $21.00 for small pumping units.
*Estimated cost per acre $20.30 for large pumping units.
*Cost of power distribution taken at the same amount as for the small unit.

The yearly cost of operation, not including pumping units, is estimated as follows:

Generating Station:		
1 Superintendent @ $150 per month for the year		1,800
1 Chief operator @ $100 " " " " "		1,200
1 Asst. " @ $100 " " " 4 months		400
Transmission Line:		
2 linemen @ $125 per month for 4 months		$1,000
Distributing System:		
4 substation operators @ $100 " " " " "		1,600
2 linemen @ $125 " " " " "		1,000
2 motor trouble men @ $100 " " " " "		800
		7,800

Estimated Depreciation, Maintenance and Operation for a Year.

Feature.	Cost in Place.	Depreciation.		Maintenance.		Operation.	Total.
		Rate.	Amount	Rate.	Amount		
Power Plant, power house and equipment.	$245,400	4%	$ 9,800	½%	$ 1,200	.....	.....
Flumes and penstocks.	30,000	10%	3,000	4%	1,200	$3,400	$18,600
Transmission line.....	103,150	8%	8,240	½%	510	1,000	9,750
Distributing system:							
Substations.....	41,850	5%	2,100	½%	210	.....	.....
Power lines.....	210,000	8%	16,800	1%	2,100	3,400	24,610
Total.....	$630,400	.....	$39,940	.....	$5,220	$7,800	$52,960

Estimated cost per acre $1.75 for small units.
" " " " $1.70 " larger "

Digitized by Google

To the above costs of features necessary to obtain power must be added the cost to each farm unit of pump and motor installation. Estimates have been made as follows for two pump units, the small unit to serve 160 acres and the larger unit to serve 320 acres:

Estimated Cost for Pump Units.

Small Unit—1,000 gallons per minute:	
Wells—2, 8" cased wells, 60' deep @ $2.00 ft.	$ 240
Pump—6" centrifugal—850 R. P. M.	315
Motor—15 H. P. 440 volt—850 R. P. M.	250
Wagon haul for pump and motor	30
Erection estimated at 1c per pound	25
Pump house—6' by 16', and well pit	100
Suction pipe, 100 ft. 6 inch @ 50 ¢	50
Discharge pipe, 65 ft. 8 inch @ 60¢	40
Reservoir—160 ft. diameter, 5 ft. deep	450
Surveying—Location of well and laterels	100
Total construction cost (160 acres)	$1,600
Estimated cost per acre $10.00.	
Large Unit—2,000 gallons per minute:	
Wells—4, 8" cased wells, 60' deep @ $2.00 ft.	$ 480
Pump—8" centrifugal—720 R. P. M.	525
Motor—30 H. P.—2,200 volt—800 R. P. M.	410
Wagon haul for pump and motor	50
Erection, estimated at 1¢ per pound	50
Pump house 8' by 20', and well pit	150
Suction pipe, 200 feet 6" pipe @ 50¢	100
Discharge pipe, 65' 10" pipe @ 75¢	50
Surveying, location of wells and laterals	185
Total construction cost (320 acres)	$2,000
Estimated cost per acre $6.25.	

To the above cost of the pump units must be added fixed charges which will have to be met each year. It will not appear at first thought to the ordinary irrigator that he will incur any expense after installing his unit except small repairs and lubricating oil. Experience in irrigation by pumping has clearly shown that it is a mistake to overlook such yearly costs as interest and taxes, and to fail to set aside each year a sufficient amount to replace the pumping unit when worn out. If these yearly amounts are not earned, then the pumping plant is an experiment and not a paying investment, and the capital invested might better be put out at interest. Accordingly these fixed yearly charges are estimated as follows:

Digitized by Google

Estimated Fixed Charges per year—Pump Units.

	Small Unit.			Large Unit.		
	Cost.	Rate.	Amount	Cost.	Rate.	Amount
Depreciation—Well*	$ 790	3%	$ 23.70	$ 630	3%	$ 18.90
" —Pump, motor and pipe	710	8%	56.80	1,185	8%	94.80
Maintenance—Well*	790	1%	7.90	630	1%	6.30
" —Pump and motor	710	2%	14.20	1,185	2%	23.70
Operation and supplies	.....	$5 H.P.	75.00	.....	$4 H.P.	120.00
Interest and taxes	1,500	8.3%	124.50	1,815	8.3%	150.60
Total	.....	.....	$302.10	.....	.....	$414.30

Estimated fixed charges per acre per year—Small Unit $1.89.
" " " " " " " Large " $1.29.

*Well includes pump house and reservoir in the case of the small unit, and pump house in the case of the large unit.

Probable Cost per Acre.—The cost per acre to the farmer, including power features and pumping units, may be summarized as follows:

Probable Cost Per Acre.

Features.	Small Pump Units.		Large Pump Units.	
	First cost per acre.	Yearly cost per acre.	First cost per acre.	Yearly cost per acre.
Power plant and power distribution	$21.00	$1.75	$20.30	$1.70
Pumping units	10.00	1.89	6.20	1.29
Total	$31.00	$3.64	$26.55	$2.99

Thus it may be seen that there is a balance of $4.50 per acre in first cost and about 65 cents per acre per year in maintenance and operation costs in favor of the larger pumping units of 2,000 gallons per minute, as compared with the small pumping units of 1,000 gallons per minute. These relative estimates are presented in order to bring out the uncertain cost of pumping development, unless the conditions under which such development would be undertaken are first known. If the substrata conditions are such that not more than 500 gallons per minute can be drawn from the ground by a single pumping unit, then the acre costs may be expected to exceed the above estimated costs for the 1,000 gallon per minute units.

In order to make a comparison of the acre costs of pumping development with the acre cost of the proposed gravity system, the most favorable conditions will be taken, such as those represented by the above cost for the larger pumping unit. In any project costing $40.00 per acre to construct, and where money brings, say, 6 per cent interest, the farm unit must be able to produce 6 per cent of $40.00, or $2.40 yearly, in addition to the

Digitized by Google

yearly cost of maintenance. In the case of the gravity project proposed, the estimated cost of construction is about $28.00 per acre, and the yearly cost of maintenance and operation not over $1.00 per acre. Following is a comparison of the yearly cost per acre of the gravity system proposed and of the possible pumping development in Fort Rock Valley at different rates of interest:

Comparative estimated yearly costs—Gravity and Pumping Systems (Electric power) Fort Rock Valley.

	Estimated Acre Costs.		Equivalent Yearly Costs.					
			Rates of Interest.					
	Construction	Operation and Maint.	3%	4%	5%	6%	7%	8%
Proposed gravity project	$28.06	$1.00	$1.84	$2.12	$2.40	$2.68	$2.96	$3.24
Pumping system	26.55	2.99	3.78	4.05	4.32	4.58	4.85	5.11

In recent years the gasoline engine has been greatly improved and makes an excellent power for pumping. However, the high cost of gasoline, resulting from its ever growing use as a fuel in engines for power driven vehicles and other uses too numerous to mention, does not make it attractive as power in competition with electricity. The low price of lower grade oils, ranging from crude oil to first distillate, and the recent adaptation of engines to use them, permit a cheaper power which is coming quite extensively into use for pumping in regions of California and Arizona, located favorably for cheap transportation of these oils from the producing fields. Success in feeding these heavier oils to the engine cylinder is attained with more or less difficulty in engines of relatively low horse power, costing not much more than gasoline engines, such as would be used for pumping from wells. Great claims are made by the makers of these engines for their low fuel cost per horse power hour, and no doubt excellent results are attained by skilful use and more or less expert knowledge in the handling. Such exacting conditions are not desirable, however, for the operation of engines driving pump units, where their good behavior during a hot dry spell, when crops are at a critical period in their growth, is a very important matter. For instance, an irrigator might in actual practice find it necessary to provide a much higher grade of oil during as much as a month of the growing season, in order to be sure of the needed continuous operation of his plant. Thus the fuel cost would be run up considerably over the cost anticipated from claims of the engine makers.

At present, low grade oils may be purchased for from four to eight cents per gallon at railroad stations in barrel lots. A

Digitized by Google

conservative estimate of fuel consumed in oil engines of from 20 to 50 horse power is about one-eighth of a gallon per horse power hour. Thus they might be expected to operate, with a fairly good oil costing about twelve cents per gallon at the farm, for one and one-half cents per horse power hour.

If we substitute in the larger pumping unit serving 320 acres, heretofore estimated to cost about $2,000 and to pump 2,000 gallons per minute, a 30 horse power oil engine, estimated to cost about $1,400 at the farm, for the motor, and a pump without the base required for a direct connected motor pump, the additional cost will be about $1,000, making the pumping unit cost about $3,000, or $9.38 per acre for the 320 acres.

The fixed charge per year for this more costly unit is estimated at $570 instead of $414.30 for the motor driven unit. In addition there will be the fuel cost ,estimated at $540, as follows: 100 pumping days averaging 12 hours each, at 2,000 gallons per minute, will cover 320 acres 1.38 feet in depth. With an estimated loss of 10 per cent in distribution this will serve 320 acres with 1.25 feet, or 15 inches, of water for the season. 1,200 pumping hours are required with 30 H. P. engine, or 36,000 H. P. hours. At one and one-half cents per H. P. hour this amounts to $540 for the season. The fixed charges added to cost of fuel for power will give $1,110 per year for 320 acres, or $3.50 per acre.

The first cost is $9.38 per acre as compared with $26.55 per acre for the electric power system, and the cost of pumping to these lands under these assumptions including interest on plant at 8 per cent, is $4.25 per acre per year compared with $5.11 for pumping by electric power as shown in the estimates.

Thus local pumping with either transmitted electric power or by distillate engine is estimated to cost more than gravity supply at $3.24 per acre. However, the quantity of water available from Silver Creek is limited, and any pumping scheme for additional lands must depend on local supply even if at a higher cost.

Of the two plans for pumping from local wells, the one by transmitted electric power and the other through the use of distillate engines, the latter is a little cheaper. On the other hand, the uncertainty as to stability in the price of oil, and the necessity of providing more expert attention than is desirable in this class of service—features which have already been mentioned—more than offset the advantage of this apparent saving. It is probable that any field of underground water supply which might be developed in this way by distillate engines would, when well opened up, turn to the use of electric power such as that made possible by completion of the Silver Lake Project.

Digitized by Google

ESTIMATED COST OF PUMPING FROM ANA RIVER SPRINGS, SUMMER LAKE VALLEY.

The cost of pumping will be shown as a first cost of constructing the following features necessary for pumping:

(1). Power development on Silver Creek.

(2). Eighteen miles of power transmission line.

(3). A pumping plant at Ana River Springs.

(4). A dam below the lowest spring for raising the water to the elevation of the highest springs, thus cutting down the head against which the water will have to be lifted.

The yearly cost of operation and maintenance of these features will also be estimated. The plan proposed on which this estimate has been made is outlined under "Pumping from Ana River Springs, Summer Lake Valley."

The pumping plant is required to pump 62 second feet against an actual head of 62 feet, or with an estimated friction head of 8 feet in pipes and about 1,600 feet of metal flume, making a pumping head of 70 feet, also 64 second feet against an actual head of 32 feet, with an estimated friction head of 3 feet, making a total pumping head of 35 feet. This would require, say three 20 second foot pumping units for each lift. In the estimate to follow, four such units are provided to insure continued pumping capacity for each lift with one unit under repair. An extra transformer is also provided for the same reason.

Following is an estimate of the power required under assumed conditions as to lift, and with estimated efficiencies of 75 per cent in pumps, 90 per cent in motors, or 67½ per cent in the pumping units, and of 90 per cent in the transmission line and transformers.

Estimated Power Requirements.

	Second feet pumped.	Pumping head feet.	Theoretical horsepower required.	Pump unit efficiency %	Horsepower required at motors.	Horsepower required from plant.
Low lift.....	64	35	255	67.5	380	420
High lift.....	62	70	495	67.5	740	820
Totals.....	126	.....	750	.....	1,120	1,240

The cost of power development on Silver Creek has been estimated (See "Estimated Cost of Pumping to Additional Lands in Fort Rock Valley"), and it will be assumed for the purpose of this estimate that the power will be developed in conjunction with uses heretofore discussed. The cost per horse power will therefore be taken at $85, the estimated cost for the larger development. The cost of operating the power plant for 3,240 H. P. required for pumping to additional lands in Fort Rock Valley was estimated at $3,400 per year, or $1.05 per horse power.

Digitized by Google

With the additional development of 1,240 horse power, operation would not exceed $1.00 per horse power, and this estimate will be used.

Estimated Cost of Pumping.

Dam—180 ft. at crest line, 26 ft. high:		
Excavation, 1,000 cu. yds. @ $0.50	$ 500	
Embankment, 7,415 " " @ 0.60	4,450	
Concrete, Corewall, 246 cu. yds. @ $15	3,690	
" Spillway conduit, 118 " " @ $20	2,360	
Miscellaneous, sheet piling and gates.	1,000	
		$12,000
Pumping Station and Equipment:		
Excavation	1,000	
Building, 50′ by 66′	3,400	
Draft and discharge tubes in place	3,000	
Pumps—4, 18″ centrifugal @ $1,450	5,800	
4, 18″ " @ 1,400	5,600	
Motors—4, 250 H. P. @ 1,350	5,400	
4, 125 " @ 850	3,400	
Transformers—4, 300 K. W. @ 1,200	4,800	
Switch boards and accessories, 900 K. W. @ $6 K. W.	5,400	
Freight and wagon haul, 170,000 lbs.	2,200	
		40,000
Power Transmission Line:		
18 mile (wood pole) @ $2,000		36,000
		88,000
Engineering, administration and contingencies, 25%		22,000
		110,000
Power—total construction cost, 1,240 H. P. @ $85		105,400
Total construction cost, pumping features		$215,400

Estimated cost per acre, 20,000 acres $10.77.

The yearly cost of operation is estimated as follows:

Power Plant—estimated at $1.00 per horse power	$1,240
Transmission Line—1 lineman @ $125 per month, four months	500
Pumping Plant—1 Superintendent @ $150 per month, twelve months	1,800
2 Assistants @ $100 per month, four months	800
	$4,340

Estimated Depreciation, Maintenance and Operation for a Year.

Feature.	Cost in place.	Depreciation.		Maintenance.		Operation.	Total.
		Rate.	Amount	Rate.	Amount		
Power plant	$105,400	*4.65%	$ 4,900	*1%	$1,060	$1,240	$ 7,200
Transmission line	45,000	8%	3,600	½%	220	500	4,320
Pumping plant:							
Building	5,500	3%	165	1%	55	.....	.....
Equipment	44,500	8%	3,560	2%	890	2,600	7,270
Totals	.....	.....	$12,225	.....	$2,225	$4,340	$18,790

Estimated yearly cost per acre, $0.94.

*Average per cent for former estimate. See "Estimated Depreciation Maintenance and Operating Costs for a Year" under "Estimated Cost of Pumping to Additional Lands in Fort Rock Valley." Power house and equipment depreciation taken at 4 per cent, and depreciation on flume and penstocks at 10 per cent.

Digitized by Google

Estimated Cost of Distribution.—The distribution system has been outlined under "Pumping from Ana River Springs, Summer Lake Valley" and consists of 1,500 feet of metal flume, capacity 65 second feet; 18 miles of high line canal ranging in capacity from 60 second feet to 20 second feet, for the high lift; 16 miles of low lift canal ranging in capacity from 60 second feet to 20 second feet; and 1½ miles of bench (metal) flume from the dam to the mouth of the canyon for distributing about 25 second feet to the 3,600 acres to be irrigated by gravity fall. All distributing canals less than 20 second feet in capacity are included in the item "Distributing Laterals and Structures" whose cost is estimated to be $3.00 per acre, with all structures made of wood. Following is estimate of cost.

Estimated Cost of Distributing System.

Flumes:			
1,500 feet metal flume	@ $5.00 per ft. in place	$7,500	
1½ miles " "	@ $0.75 " " " "	5,940	
200 feet 25 sec. ft. capacity	@ $2.80 " " " "	560	
			$ 14,000
Canals—34 miles:			
Excavation—190,900 cu. yds.	@ $ .25	$47,750	
Fencing — 34 miles	@ $125.00	4,250	
Telephone — 34 miles	@ $250.00	8,500	
Culverts — 10	@ $ 50.00	500	
Bridges — 4	@ $100.00	400	
Right of way and damages, estimated		5,000	
			66,400
Distributing laterals and structures:			
20,000 acres @ $3.00			60,000
			140,400
Engineering, administration and contingencies, 25%			35,100
Total construction cost			$175,500

Estimated cost per acre, 20,000 acres, $8.78.

Probable Total Cost and Cost per Acre of Ana River Project.—On the assumption that power is developed on Silver Creek in conjunction with other uses, the total construction cost and yearly cost of maintenance and operation for the project, together with equivalent yearly costs per acre, with interest at different rates, is tabulated as follows:

Feature.	Construction Cost—Dollars.		Operat'n and Maint. cost dollars.	Equivalent Yearly Costs—Dollars. Rates of Interest.					
	Total.	Per acre.	Per acre.	3%	4%	5%	6%	7%	8%
Pumping....	215,400	10.77	.94	1.26	1.37	1.48	1.59	1.69	1.80
Distribution	175,500	8.78	.75	1.01	1.10	1.19	1.28	1.36	1.45
Totals.....	390,900	19.55	1.69	2.27	2.47	2.67	2.87	3.05	3.25

Digitized by Google

It will be noted that the yearly cost of operation and maintenance for the distribution system is taken at 75 cents, whereas in the proposed Silver Lake Project it is taken at $1.00 per acre. The supervision of maintenance and operation would be handled in connection with the pumping features, and as there is no reservoir to maintain and operate, as in the case of the gravity project, it is thought that maintenance and operation can be taken at the lower figure.

In conclusion, this estimate shows an initial cost of $19.55 per acre, with an annual cost of $1.69 per acre, and the project would have to earn $3.25 per acre each year to pay 8 per cent interest on the original investment, with a probable supply of about 15 or 16 inches of water on the land. In order to make a comparison of the cost of this project with the reclamation of a part of the bed of Silver Lake and with the gravity project proposed, the cost of operation and maintenance of the pumping plant, or $0.94 per acre per year, may be capitalized at, say, 8 per cent, and added to the first cost of construction, $19.55 per acre. $0.94 capitalized at 8 per cent amounts to $11.75, and this added to the $19.55 makes an equivalent construction cost of $31.30 per acre as against $40.75 for the reclamation of the bed of Silver Lake, and $28.06 per acre for the proposed gravity project. See "Probable Cost per Acre of Reclaiming Silver Lake Bed."

If the maintenance and operation cost of $0.94 per acre per year is capitalized at 6 per cent, the value is $15.65, and the total equivalent construction cost then becomes $35.20 instead of $31.30.

OPERATION AND MAINTENANCE

With the operation of an irrigation system there goes the maintenance of the system, the two being so closely connected that in cost-keeping they are generally included under the one head of Operation and Maintenance. With operation and maintenance is sometimes included what are more properly termed Betterments. For example, the relocation of a bad portion of a canal, the replacing of a badly located headgate by a better one, perhaps of concrete instead of timber, or the concrete lining of portions of canals where the seepage rate is high.

The Reclamation Service in earlier years included with operation and maintenance all betterments. The tabulation of operation and maintenance costs of Reclamation Service projects for the year 1912, shown in Deschutes Project report, Oregon Cooperative Work, includes such betterments costs. It is often difficult, in the case of an uncompleted irrigation project, to determine or fix upon the proper basis of area for determining the charge per acre. A project may have storage provided and all main canals constructed for, say, 75,000 acres, with but one unit

Digitized by Google

of, say, 10,000 acres being served, and of this unit perhaps no more than 1,000 acres actually irrigated. Owing to these difficulties many of the earlier and later operation and maintenance reports of the Service appear to be conflicting. For the year 1912 on the Truckee-Carson Project, for example, the whole area of the project, approximately 90,000 acres, was used as the basis for determining the cost per acre, which on that basis amounted to 50 cents an acre. On the basis of the gross area really being served, about 52,000 acres, the cost was 89 cents per acre, and on the basis of the area actually irrigated, approximately 37,000 acres, the cost was $1.24 per acre.

In the following tabulation of operation and maintenance cost for Umatilla, Orland, Truckee-Carson and Klamath Projects from the date of their earliest records of operation and maintenance cost-keeping, the acre costs for land actually irrigated and for gross area actually being served are given.

Operation and Maintenance Cost per Acre U. S. Reclamation Service Projects.

Year.	Umatilla, Oregon.		Orland, California.		Truckee-Carson, Nevada.		Klamath, Oregon,	
	1	2	1	2	1	2	1	2
1908	$3.09	.....	.....	.....	.....	.....	.....	.....
1909	2.42	.....	.....	.....	.....	$1.34	$ .53	$ .79
1910	2.01	$12.29	.....	$2.57	.....	1.42	.58	.80
1911	1.77	9.05	$0.49	2.55	.....	1.33	.69	.84
1912	1.56	5.90	.94	3.11	$ .89	1.24	.46	.59
1913	1.97	6.55	.93	2.02	.92	1.11	.78	1.13
1914	1.55	5.16	1.34	2.61	.81	1.06	1.05	1.47

1—Irrigable. 2—Irrigated.

In the Umatilla Project, owing to the character of topography and soil and also to climate, it has proven a very slow prosess to bring the soil under cultivation. For this reason the area actually irrigated in the several units to which water is supplied is comparatively small and the acre cost of the land actually irrigated is therefore very high, as appears in the tabulation. This cost, however, as well as the cost per acre of land irrigable, is decreasing each year.

In the Orland Project, the year 1913 showed a decrease from the year 1912. The year 1914 would undoubtedly have shown a further decrease but for the fact that exceptionally heavy storms caused much damage to canals and to the headgates at the main diversion from Stony Creek. The repairs to these damages of course properly belong to maintenance, and were therefore so charged.

In the Klamath Project there is a small decrease in cost of operation and maintenance for the year 1912 from that of preceding years. For the year 1913, however, the acre cost for

Digitized by Google

both irrigable and irrigated land increased, and for the year 1914 a still further increase in cost is noted. This increase in cost was due principally to the fact that the earlier wooden structures of the project began to be replaced about this time, but also in part to the fact that earlier operation and maintenance had not been kept up to the higher standard found necessary by this time. There was also included in the year 1913 a drainage charge of about forty cents per acre irrigable, and about sixty-one cents per acre irrigated.

Silver Lake Project can probably be better compared to Klamath Project or to Truckee-Carson Project than to either of the others tabulated. The mean cost of the four projects for the year 1914, however, is $1.19 per acre irrigable. It would appear, therefore, that operation and maintenance, including drainage, might reasonably be expected to not exceed $1.20. The higher cost per acre irrigated of course gradually reduces, reaching finally that of the area irrigable when the entire area is irrigated.

Attention is called to the fact that wooden structures, such as turnouts, gates, etc., on the Klamath Project, had to be replaced about the fifth or sixth year after construction. This should be anticipated for the Silver Lake Project, the present estimate for which is based on all minor structures, such as turnouts and gates, being of lumber. Structures have been designed and estimated in wood, because of the long distance from railroad transportation at the present time and the probability that by the time they are old enough to require replacement, railway transportation will have reached the project.

Digitized by Google

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS.

SUMMARY.

A summary in the form of a synopsis appears in the first pages of the report.

CONCLUSIONS.

It appears from the investigations:

(1). That the proposed Silver Lake Project proper, consisting of Silver Lake, Paulina, Horning Bend and Fort Rock Units, a total of 48,600 acres, is both physically and economically feasible at the estimated cost of $28.10 per acre, with interest charges of not to exceed six per cent, if legal difficulties do not prevent the diversion of Sycan Marsh waters from the Klamath watershed.

(2). That any development including the Silver Lake Unit should also include provision for a storage supply of approximately 4,000 acre feet for the 8,000 acres in the vicinity of the town of Silver Lake, having adjudicated rights to natural flow of Silver Creek, at the estimated cost of $2.00 per acre distributed over the entire 8,000 acres.

(3). That the drainage and irrigation of about 9,000 acres in Paulina Marsh as proposed is feasible at the estimated cost of $25.20 per acre, but that it is doubtful, considering the present value of the lands for wild hay, whether this value would be increased by the amount of the cost of such construction until such time as better transportation facilities are afforded the project.

(4). That the reclamation of part or all of Silver Lake bed may be practicable and desirable at some time in the future, when a better knowledge is had of the amount of water which will have to be cared for, but that this feature should be given little if any weight at this time in the consideration of the project proper.

(5). That the proposed summer power development on Silver Creek is possible at a comparatively low cost in connection with development of the Silver Lake project proper, but that its feasibility is largely a question of market or use for the power.

(6). That the proposal to irrigate lands east of Summer Lake from Ana River by pumping is entirely feasible and practicable in connection with the Silver Lake project proper, but that the area possible to serve may be materially modified by topographic survey of the irrigable lands and by soil surveys.

(7). That the practicability of irrigating any large body of land in the Fort Rock or Christmas Lake valleys by pumping from wells is very doubtful, but that the power for pumping for a very large area can be developed and transmitted to the lands at a comparatively low cost, if feasible wells are developed.

Digitized by Google

RECOMMENDATIONS.

In view of the conclusions reached as to the feasibility of the several units, it is recommended:

(a). That it be the policy of the United States and the State to promote the development of the Silver Lake Unit as immediately feasible, and the Paulina Marsh Unit whenever the owners of land under it express a desire for the development.

(b). That it also be the policy to promote the development of the Paulina, Horning Bend and Fort Rock Units whenever adjudication of the waters of Klamath watershed or agreement relative thereto shows water to be available from Sycan River and from Chocktoot, Long and Coyote creeks as proposed.

(c). That continuous records be kept of discharge of Sycan River, of Chocktoot, Long and Coyote creeks above Sycan Marsh, and of Silver, Bridge and Buck Creeks, tributaries to Silver Lake; also that records be kept of fluctuation of Silver Lake.

(d). That the Ana River pumping unit for possibly as much as 20,000 acres be considered whenever the Silver Lake Project proper is taken up.

(e). That Silver Lake bed reclamation be not considered until such time as the operation of the main project has developed a fuller knowledge of the probable amount of water that will require to be taken care of and whether it can be maintained sufficiently free of alkalies to be available for irrigation.

(f). That the possibility of pumping from wells to any large area in the Fort Rock and Christmas Lake valleys be considered only as a possibility until such time as test wells with gasoline engine pumps have demonstrated the existence of sufficient ground water supply and practicable wells at reasonable depth.

(g). That public lands be withdrawn by the United States for Thompson Valley and Buck Creek reservoirs, and that the unappropriated waters of streams tributary to Silver Lake and Sycan Marsh be withdrawn from appropriation by the State.

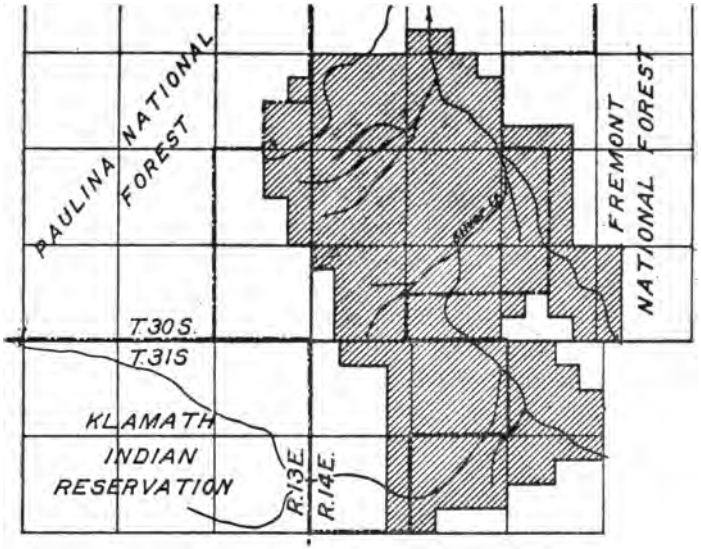
LAND AND WATER WITHDRAWALS.

In compliance with the terms of agreement, May 5, 1913, between the United States and the State of Oregon, withdrawal of unpatented lands of Thompson Valley reservoir site was made by the Secretary of the Interior December 13, 1913. As a result of the reservoir surveys, it has appeared desirable to modify this withdrawal slightly.

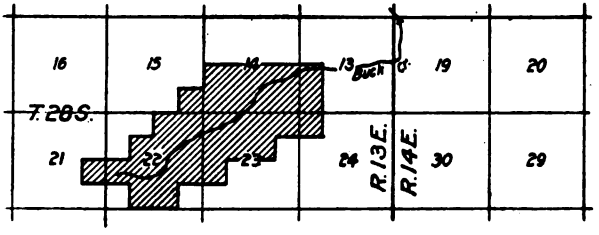
Withdrawal of unpatented lands for Buck Creek reservoir, together with modification of withdrawal for Thompson Valley reservoir, has been recommended. These withdrawals are shown on Sheet No. 43.

Digitized by Google

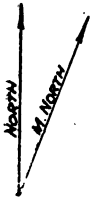
PUBLIC LAND WITHDRAWALS



THOMPSON VALLEY RESERVOIR SITE



EMORY RESERVOIR SITE



OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon

Project SILVER LAKE
Feature Public Land Withdrawals
Designed by ____ Date ____
Surveyed by ____
Drawn by Weare 10-1915
Traced by Rullman "
Checked by Weare "
Scale 2 Mile Project File No. 43

Digitized by Google

Digitized by Google

Under date of November 10, 1913, all unappropriated waters of Sycan or Squaw River and tributaries, including Chocktoot, Long and Coyote Creeks, were withdrawn for irrigation, storage, power and domestic supply, under application No. 3285.

Under date of October 11, 1915, all unappropriated waters of Ana River, tributary of Summer Lake, were withdrawn for irrigation, power, domestic use and for storage purposes, under application No. 4570.

Under date of October 11, 1915, all unappropriated waters of Silver Creek, West Fork of Silver Creek, Buck Creek, Duncan Creek, Bridge Creek, Bear Creek, and all other streams tributary to Silver Lake and Paulina Marsh, were withdrawn for irrigation, power and domestic use, and for storage in Thompson, Antelope, Emory, Owsley, Egli, Silver Lake and other reservoirs in the Silver Lake drainage basin, under application No. 4571.

COST OF INVESTIGATIONS AND REPORT.

Following is distribution and total cost of investigations to October 1, 1915. The estimated cost of completing and printing report, 1,000 copies, is $750.00.

Summary of Work and Costs.

	September 30, 1915 Paid by United States	Paid by Oregon
Surveys—Silver Lake Project proper	$ 742.22	$1,016.86
Surveys—Sycan Marsh	211.00	192.75
Examination Ana River	211.00	178.50
Office computations, designs and estimates	1,576.45	1,380.26
Totals	$2,740.67	$2,768.37

Distribution of Costs.

Surveys Silver Lake Project (Including Sycan Marsh and Ana River):		
Labor	1,147.10	792.11
Material and Supplies		259.78
Other Expenses	17.12	336.22
	1,164.22	1,388.11
Office computations, designs and estimates:		
Labor	1,564.55	1,258.00
Material and Supplies	11.90	11.47
Other Expenses		110.79
	$1,576.45	$1,380.26

Digitized by Google

Digitized by Google

Digitized by Google

INDEPENDENT PRINTING CO.
PORTLAND, OREGON

Digitized by Google

Digitized by Google

Digitized by Google

YC 68114

Digitized by Google

Digitized by Google